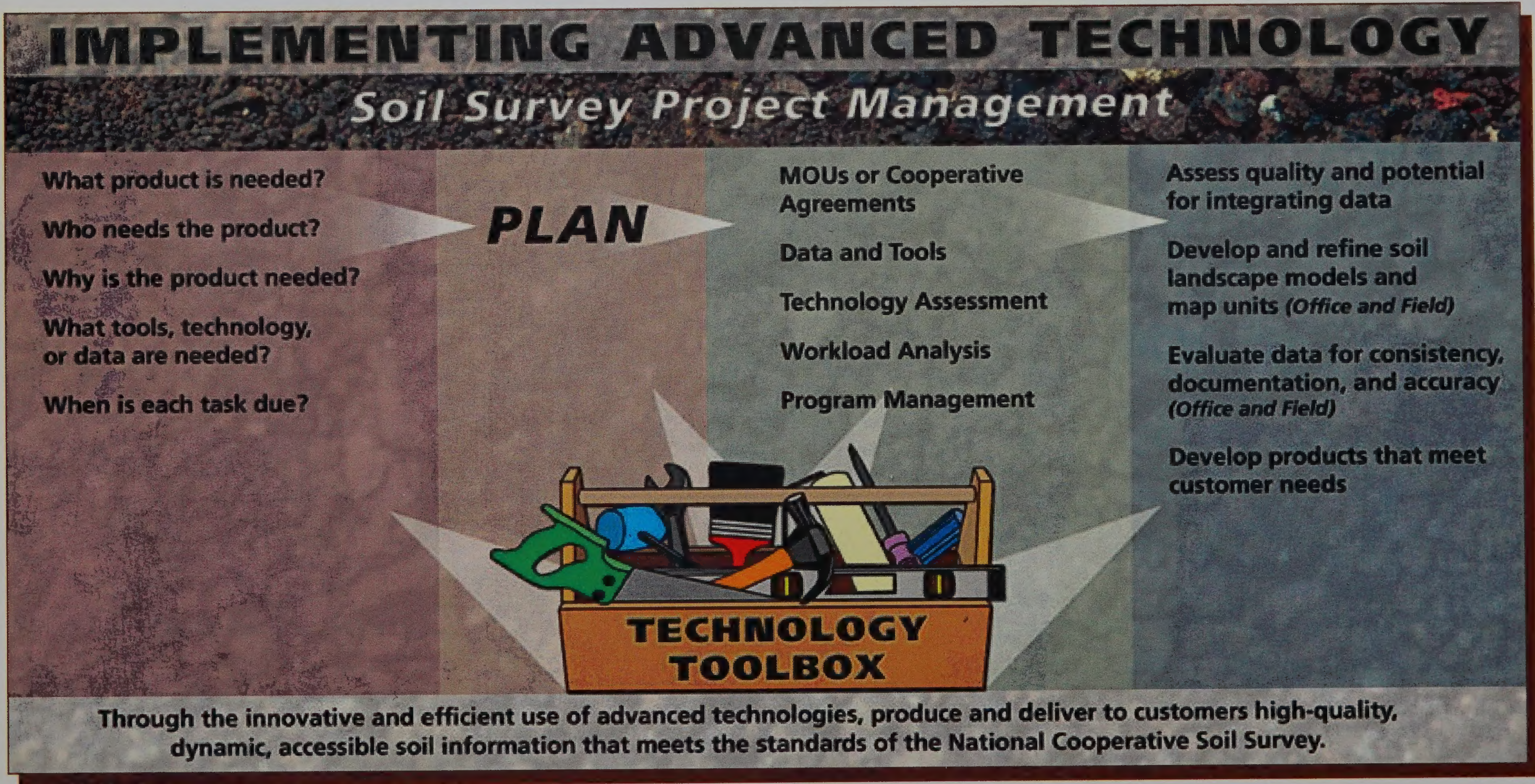
BLM
National Training Center

Advanced Technology in Soil Mapping

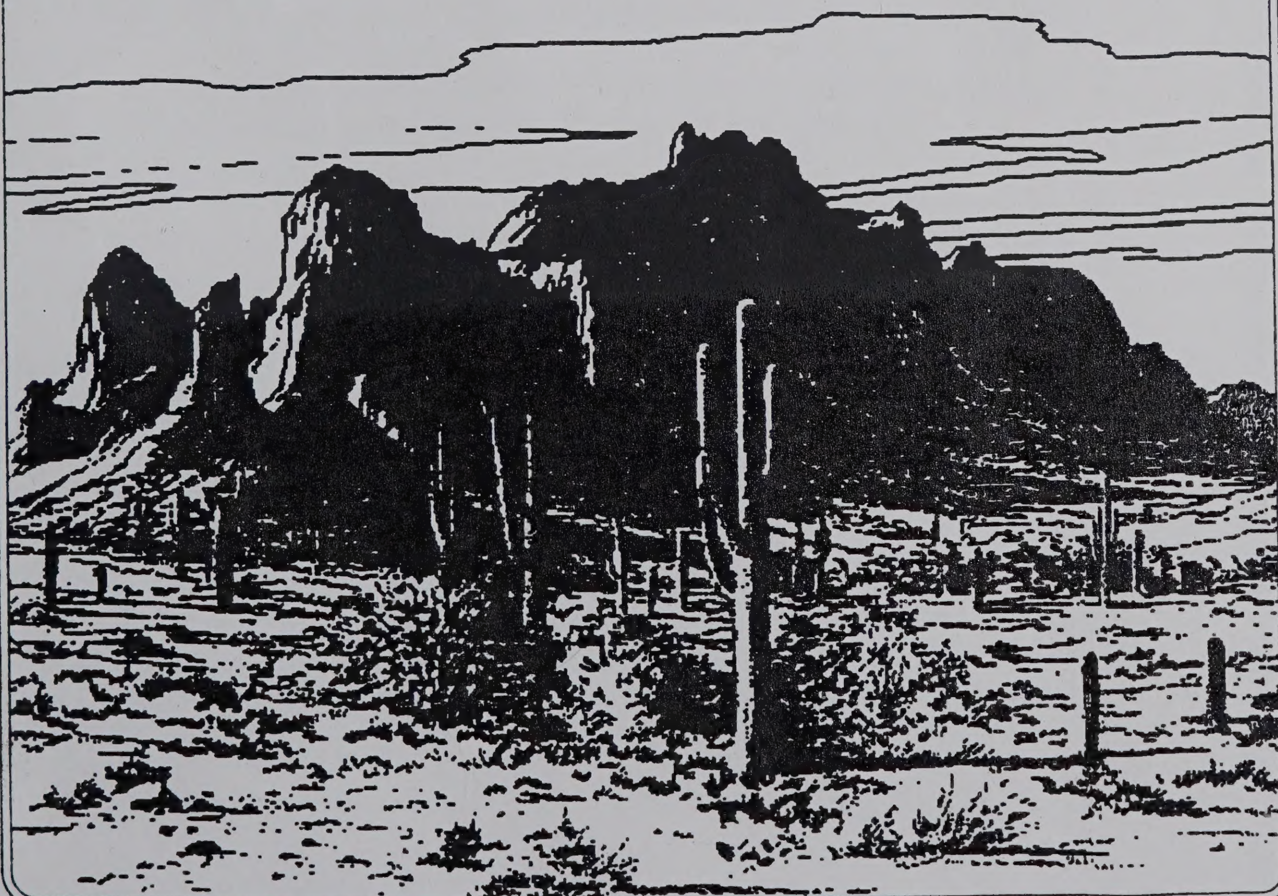
Course 7000-05

March 15 – 19, 2004

Phoenix, Arizona



Welcome to the BLM NATIONAL TRAINING CENTER



THE NATIONAL TRAINING CENTER

Information About the Facility

INFORMATION ON NTC'S HOME PAGE:

The National Training Center's (NTC), web site is www.ntc.blm.gov This site contains a wealth of information about the facility, hotels, general policy, weather, entertainment, maps, building layout, etc.

NTC OPERATING HOURS

NTC is open from 7:00 a.m. to 5:00 p.m., Monday through Friday. When arriving at NTC, visitors can get class and meeting information from the electronic bulletin board on the ground floor, Building C. To get directions and answers to other questions, visitors should see the receptionist on the ground level of Building C.

NTC TRAINING LEAVE POLICY

When attending courses at NTC, the following policy applies for leave.

- ❑ Annual Leave: No annual leave is authorized except in emergencies. Report all such emergencies to the training coordinator.
- ❑ Sick Leave: If a trainee must miss class or leave class due to an illness, this absence should be reported to the training coordinator as soon as possible.
- ❑ Field Trips: All field trips are part of the training and are not discretionary. Only emergencies and sickness are excusable absences.

All leave will be recorded by the training coordinator and reported to the appropriate office.

OFF LIMITS AREAS AT NTC

Many NTC areas are kept locked during business hours for security reasons. For access to such areas, visitors should see an NTC staff coordinator or the receptionist. Valuables should not be left unattended in classrooms.

PUBLIC TRANSPORTATION

Rental cars are not authorized for transportation for NTC training, for travel to and from the airport, etc.
NTC is within a short walk of the Metro Center bus terminal and even closer to some bus stops. Numerous bus lines offer access to the Phoenix metropolitan area from the terminal. Information on bus schedules can be obtained from the reception desk. In addition, the SuperShuttle provides fast transportation to and from Phoenix's Sky Harbor Airport. Information about the SuperShuttle was sent to you previously.

PARKING

NTC has parking for 240 vehicles. Visitors should be cautioned not to park in the Country Buffet lot. For large events, where we may exceed our parking spaces, employees may be asked to park at Metro Center Mall on the day of the event.

NTC'S SMOKING POLICY

NTC is a nonsmoking facility. Smoking is permitted only at the designated smoking area behind the elevators on the first floor. Smoking materials must be discarded in proper containers.

LUNCHROOM AND BREAK FACILITIES

NTC's kitchen and lunchroom are on the second level of Building A. The kitchen is equipped with a dishwasher, microwave ovens, and refrigerators for daily lunch storage. The kitchen also has vending machines for coffee, espresso, snacks, and soft drinks. If food or drink is spilled on the carpet, an NTC staff coordinator should be notified immediately so that the spill can be cleaned up before it permanently stains the carpet.

The table and chairs within the lunchroom and on the outside deck are for employee and visitor use. All are expected to clean up after themselves.

TELEPHONE AND MESSAGE SERVICES

The NTC receptionist will take telephone messages for visitors, but NTC is not staffed to handle large volumes of telephone traffic. We ask visitors to limit their telephone use to official business or emergency personal calls and avoid creating

incoming calls by not asking people to call them back. We also ask visitors not to tie up NTC staff phones or offices.
For the convenience of our visitors, telephones are located on the second floor of Building A adjoining the lunchroom. If visitors need to refer to our phone number, they should use **(602) 906-5500**. Our fax number is (602) 906-5555. Messages for visitors will appear on television monitors outside the classrooms, and faxes can be picked up at the reception desk in Building C on the ground floor.

GENERAL VEHICLE USE POLICY

It is the policy of the BLM National Training Center to provide transportation for trainees, instructors, and meeting participants between hotels where lodging is blocked by NTC. This policy supplements Bureau policy found in BLM Manual Handbook 1525-1 - Fleet Management and will be incorporated into an NTC supplement to the BLM manual. Further policy and guidelines for reimbursement of vehicle expenses for official travel can be found in the Federal Travel Regulations Chapter 301 - Travel Allowances.

When accepting keys to a Government vehicle, BLM employees are responsible for abiding by the Government vehicle use policy. This policy is placed in each Government vehicle.

Government vehicles are used to transport groups to and from the hotel and NTC, to eating establishments (within a 10 mile radius), grocery stores, and temporary duty stations.

A few “heads-up” items:

- ❑ Always be sure that all passengers are **wearing a fastened seat belt**.
- ❑ **Alcohol is never permitted** in a government vehicle.
- ❑ **Smoking is not allowed** in government vehicles.
- ❑ Propriety of vehicle use is being questioned more frequently through the whistle blowers hotline and citizens’ calls to GSA/Government offices.
- ❑ Even the **appearance** of improper use may be challenged and cause NTC to lose jurisdiction over the case, and the ability to defend the user.
- ❑ **Improper use of government vehicles is punishable with a mandatory 30-day suspension without pay.**
- ❑ Rental vehicles are bound by the same vehicle policy as government owned and licensed vehicles if the employee will be reimbursed when government transportation is unavailable.
- ❑ Transportation for **personal use**, such as entertainment, sight seeing, or weekend travel, can be coordinated by groups interested in sharing rental vehicle costs.

COMPUTER ROOM

There is a computer area available for students to use before class, at lunch, or after class. It is located on the first floor in Building B Room 101. There are two computers; a Unix and an NT. They can be used to check e-mail, word process and print.

FITNESS ROOM

The fitness room is available to NTC staff, visiting instructors and students during normal duty hours. Sign out keys to instructors and students are available at the reception desk. Guests must take care of the equipment. The more it's abused the less time it will be around for everyone to use.

NTC EEO COUNSELORS

The National Training Center EEO Counselors are:

Lorraine Farley	(602) 906-5597	NTC
Ceci Sturm	(602) 417-9218	AZSO

THE NATIONAL TRAINING CENTER

Security procedures for visitors at the BLM National Training Center

The BLM National Training Center (NTC) has implemented the following security requirements, which will be strictly enforced during your visit:

1. All visitors will be required to enter and exit through the main entrance on the north side of the building.
2. Upon check-in, visiting BLM personnel will be required to display their Government ID card (Smart Card or DI-238A), with photo. You will then be issued a visitor's pass or name tag, which must be worn at all times while on the premises.
3. All visitors will be required to sign the visitor's roster each day, upon check-in.
4. Under no condition should a visitor open an exterior gate for other visitors.
5. All visitors, and staff, must vacate the premises no later than 6:00 pm each day.

Your cooperation will be greatly appreciated.

NTC Classroom Temperatures

In accordance with the President's new energy conservation initiatives, new thermostats have been installed at NTC. These new thermostats will be set at the following temperatures, in accordance with the lease:

cooling season - approx. 75 - 76 degrees (the lease only requires 76 - 80 degrees)

heating season - approx. 69 - 70 degrees (the lease requires 65 - 70 degrees)

The thermostats will be pre-set, and the lockout function will be activated so there will be no manual adjustment available in the classrooms. Please dress appropriately.

THE NATIONAL TRAINING CENTER

Travel Information

***Note to dial numbers in the Phoenix Area you must use the area code**

AIRPORT SHUTTLE

The Super Shuttle service is available for transportation to and from the airport and may be arranged by signing up in the Reception desk or by calling **602-244-9000 at least 24 hours before your departure**. You will need to provide them with the name of your airline, the departure time, and the NTC address - **9828 N. 31st Avenue, Phoenix, AZ 85051 (major streets - 31st Avenue and Peoria)**. Ask them to pick you up at the **NORTH** side of the NTC complex. Coupons are available from NTC for discount rates.

National Training Center's Travel Agency

Omega World Travel

Reservations **-877-434-1575**

Toll Free 24 Hr Emergency Number **1-800-964-6342**

Web site: ***www.owt.net/government***

Super Shuttle/Cabs

Super Shuttle - **602-244-9000**

Checker Cab - **602-257-1818**

Yellow Cab - **602-252-5071**

Rental Car Information

Avis	**602-273-3222**	Sky Harbor Airport
Courtesy Rent-A-Car	**602-273-7503**	101 N. 24th St. Phoenix, AZ
Enterprise Rent-A-Car	**623-931-9275**	4742 W. Gendale Ave. Gendale, AZ
Hertz	**602-267-8822**	Sky Harbor Airport
Toll Free	**1-800-654-3131**	
National Car	**602-275-4771**	1403 S. 22nd St. Phoenix, AZ
Thrifty Rent-A-Car	**602-244-0311**	4114 E. Washington St. Phoenix, AZ
Budget Rent-A-Car	**602-267-4000**	Sky Harbor Airport
Dollar Rent-A-Car	**602-275-7588**	50 S. 24th S. Phoenix, AZ

Note: Be sure to ask for Government rates. You may need to show your Travel Authorization Number and Credit Card.

THE NATIONAL TRAINING CENTER
Travel Information

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Airline Numbers

Alaska Airlines	1-800-426-0333	http://www.alaskaair.com
American Airlines	1-800-433-7300	http://www.americanair.com
America West	1-800-235-9292	http://www.americawest.com
Continental	1-800-231-0856	
Delta Airlines	1-800-221-1212 602-258-5930	http://www.delta-air.com
Northwest	1-800-225-2525	http://www.nwa.com
Shuttle by United	1-800-748-8853	
Southwest	1-800-435-9792 602-273-1221	http://www.southwest.com
TWA	1-800-221-2000	
United	1-800-241-6522	http://www.ual.com
US Air	1-800-428-4322	

THE NATIONAL TRAINING CENTER

Medical Information

***Note to dial numbers in the Phoenix Area you must use the area code**

PHYSICANS **Physicians Referral Service** John C. Lincoln Hospital 24-Hour Hotline **602-943-1111**	**Dr. Clayton Wainwright, D.D.S.** 9460 W, Peoria Avenue, Suite G Peoria, AZ **623-412-7943**
Physicians Referral Service Thunderbird Samaritan Hospital 24-Hour Hotline **602-230-2273**	**HOSPITALS/EMERGENCY CENTERS** **Nextcare** Urgent & Family Medicine 2423 W. Dunlap Ave. #C Phoenix, AZ **602-216-6862**
Arizona Asthma & Allergy Institute 5310 W. Thunderbird Avenue Suite 200 Glendale, AZ **602-843-2991**	**John C. Lincoln Hospital** 250 E. Dunlap (near Central & Dunlap) Phoenix, AZ **602-943-2381**
DENTISTS **Americare/Dental Center** In Sears (Metro Center) 10001 N. Metro Parkway Phoenix, AZ **602-995-8862**	**Thunderbird Samaritan Hospital** 5555 W. Thunderbird Road Glendale, AZ **602-588-5555**
Arizona Dental Center 5716 North 19th Avenue Phoenix, AZ **602-249-1616**	**Phoenix Baptist Hospital** 6025 N. 20th Avenue Phoenix, AZ (19th Ave & Bethany Home) **General - 602-249-0212** **Emergency - 602-246-5747** **RN's 24 hrs day - 602-246-5555**

THE NATIONAL TRAINING CENTER

Child Daycare Information

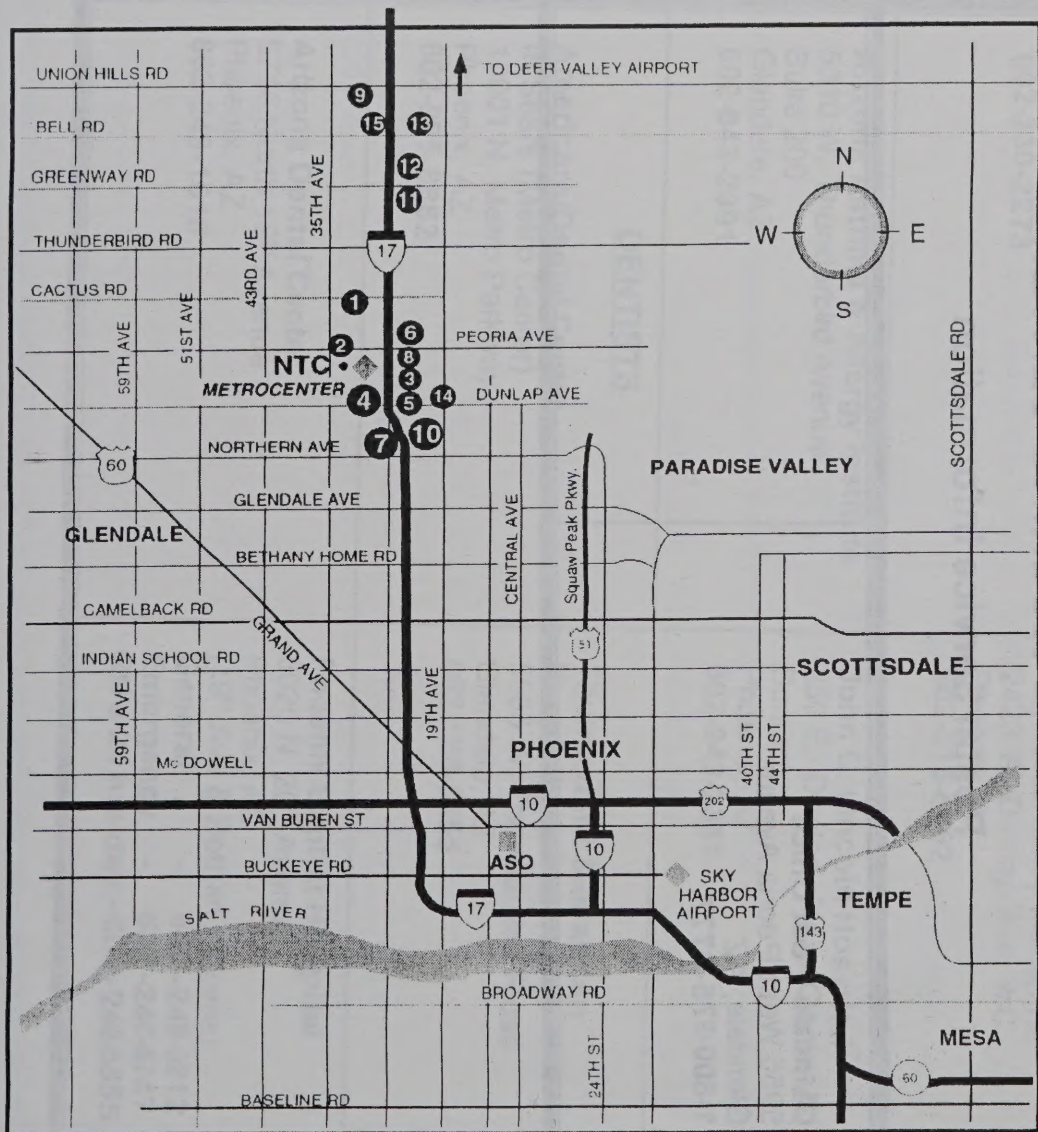
*Note to dial numbers in the Phoenix Area you must use the area code

KinderCare Learning Center 10653 N.25th Ave. Phoenix, AZ 85029 (25th Ave. & Peoria) **602-371-8881**	**KinderCare Learning Center** 12010 N. 43rd Ave. Glendale, AZ 85304 (43rd Ave. & Cactus) **602-547-9640**

THE NATIONAL TRAINING CENTER

Postal Service Information

Glendale Post Office 5955 West Peoria Avenue Glendale, AZ **1-800-275-8777**	



1. Ramada Inn
12027 N. 28th Drive
(602) 866-7000

2. Royal Suites
10421 N. 33rd Avenue
(602) 942-1000

3. Sierra Suites
9455 N. Black Canyon Hwy.
(602) 395-0900

4. Four Points Barcelo Hotel
10220 N. MetroPkwy East
(602) 997-5900

5. Crescent Hotel
2620 West Dunlap Ave.
(602) 943-8200

6. Crowne Plaza Hotel
2532 West Peoria Ave.
(602) 943-2341

7. Residence Inn
8242 N. Black Canyon Frwy.
(602) 864-1900

8. Court Yard by Marriott
9631 N. Black Canyon Hwy.
(602) 944-7373

◆ BLM National Training Center
9828 N. 31st Ave.
Phoenix, AZ 85051
(602) 906-5500

9. Wyndham Garden Hotels
2641 W. Union Hills Dr.
(602) 978-2222

10. Hampton Inn
8101 N. Black Canyon Hwy.
(602) 864-6233

11. Embassy Suites
2577 W. Greenway Rd.
(602) 375-1777

12. La Quinta Inns Inc.
2510 West Greenway Rd.
(800) 993-0800

13. Comfort Inn
1711 W. Bell Road
(602) 866-2089

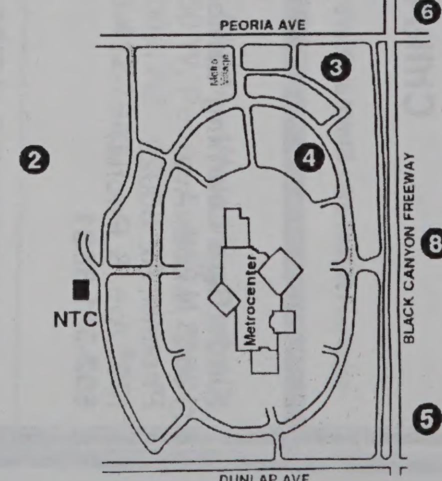
14. Homestead Village
2054 W. Dunlap
(602)944-7828

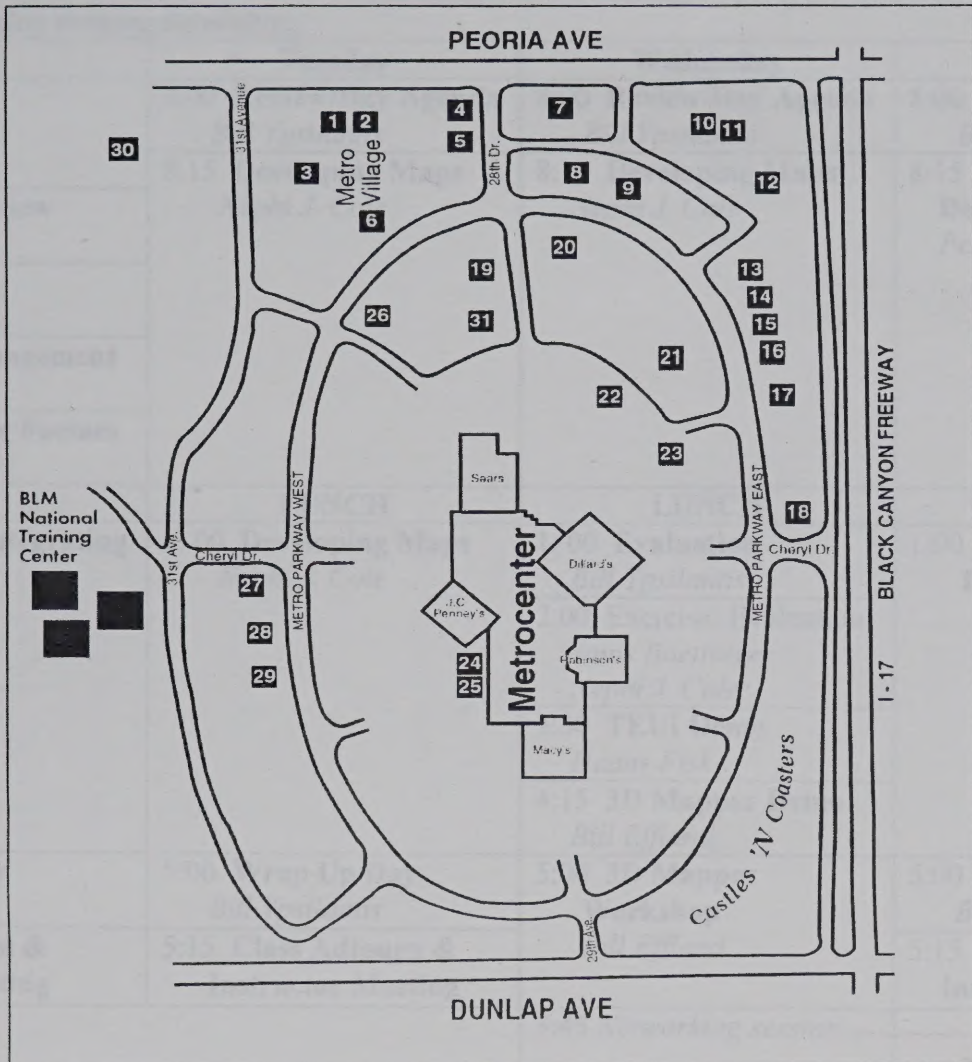
15. Red Roof Inn
17222 N. Black Canyon Hwy
(602) 866-1049

16. Candlewood Hotel
11411 N. Black Canyon Hwy
(602) 861-4900

■ BLM Arizona State Office
222 N. Central Avenue
Phoenix, AZ 85004
(602)417-9500

METROCENTER AREA MAP





What's around Metro?

1 China Gate
2 Wendy's
3 Yogurt Cup
4 Sizzler
5 Swensen's Ice Cream
6 Mimi's
7 Burger King
8 China Inn
9 Olive Garden
10 Ribsters Flashback
11 Coco's
12 Premier Inns Hotel
13 Oriental Restaurant
14 Mamma Mia
15 Bennigan's
16 El Torito
17 Stuart Anderson's Black Angus
18 Souper Salads
19 Hungry Hunter
20 Whataburger
21 FourPoints Barcelo Hotel Restaurant
22 United Artists Metro Park Cinema
23 Peter Piper Pizza
24 Metro Food Court & Ruby Tuesday's
25 Harkins Metro Movies
26 Java Centrale
27 Old Country Buffet
28 Trader Joe's
29 YC's Mongolian BBQ
30 Garcia's Mexican Resturant
31 Red Lobster

7000-05 Advanced Technology in Soil Mapping

March 15-19, 2004 -- BLM National Training Center (Phoenix, Arizona)

Course Goal: Participants will effectively apply concepts of digital mapping using appropriate technology and resources to enhance soil mapping techniques, data evaluation, and product delivery.

Target audience: Interagency Soil Scientists and those with soil scientist's duties **Class size:** 10-12 participants

Prework: First module (FREE) of ESRI course Learning ArcGIS 8, Part I. AND Pre-assessment sent via e-mail in Word format

Special event: Monday evening networking

Monday	Tuesday	Wednesday	Thursday	Friday
8:00 **Welcome & Introductions** *Bill Ypsilantis*	8:00 **Review/Day Agenda** *Bill Ypsilantis*	8:00 **Review/Day Agenda** *Bill Ypsilantis*	8:00 **Review/Day Agenda** *Bill Ypsilantis*	8:00 **Review/Day Agenda** *Bill Ypsilantis*
8:40 **Course Overview** *Bill Ypsilantis*	8:15 **Developing Maps** *Nephi J. Cole*	8:15 **Developing Maps** *Nephi J. Cole*	8:15 **Product Development** *Pete Biggam*	8:05 **Final Assessment Project Workshop**
9:10 **Planning** *Earl Lockridge*				9:15 **Project debrief** *Earl Lockridge*
10:20 **Project Management** *Earl Lockridge*				10:25 **SoLIM Demo** *Bill Effland*
11:30 **Soil Forming Factors** *Janis Boettinger*				11:00 **Debrief Course with participants** *Cadre*
LUNCH	**LUNCH**	**LUNCH**	**LUNCH**	
1: 00 **Mapping - Integrating Data** *Pam Clemmer*	1: 00 **Developing Maps** *Nephi J. Cole*	1: 00 **Evaluation** *Bill Ypsilantis*	1:00 **Final Assessment Project Workshop**	1:00 **Debrief Course With Cadre** *Ann Hutchinson*
		2:00 Exercise: Evaluation *Janis Boettinger, Nephi J. Cole*		2:00 End
		3:30 **TEUI Demo** *Haans Fisk*		
		4:15 **3D Mapper Demo** *Bill Effland*		
5:00 **Wrap Up Day** *Bill Ypsilantis*	5:00 **Wrap Up Day** *Bill Ypsilantis*	5:00 **3D Mapper Workshop** *Bill Effland*	5:00 **Wrap Up Day** *Bill Ypsilantis*	
5:15 **Class Adjourn & Instructor Meeting**	5:15 **Class Adjourn & Instructor Meeting**		5:15 **Class Adjourn & Instructor Meeting**	
		5:45 *Networking session* →	moved to thurs eve	

file: schedule - 1 page rev Feb 26 2004

10 minutes breaks will be taken every 1 to 1 ½ hours

Advanced Technology in Soil Mapping
Course 7000-05
March 15 – 19, 2004
Phoenix, Arizona

Crystal Briggs Title: Washington State Univ. Dept. of Crops and Soils P.O Box 646420 Pullman, WA 99164-6420 509-335-7817 crystal1@mail.wsu.edu	**David Howell** State Soil Survey GIS Specialist USDA-NRCS 1125 16th Street, Room 219 Arcata, CA 95521 707-822-7133 David.howell@ca.usda.gov
Robert Davidson Forest Soil Scientist Uinta NF Heber District 2460 South Hwy 40 Heber City, UT 84032 435-654-7233 radavidson@fs.fed.us	**Arnie Irwin** Soil Scientist Bureau of Land Management 1425 Fort St. Buffalo, WY 82604 307-684-1171 arnie_irwin@blm.gov
Don Fallon TERRA Program Manager Region 4 Regional Office Forest Service 325 24th Street Ogden, UT 84401 801-625-5361 dfallon@fs.fed.us	**Ken Kanaan** Soil Scientist/Ecologist Pike San Isabel National Forest 2840 Kachina Dr. Pueblo, CO 81008 719-553-1513 kkanaan@fs.fed.us
Fred Fischer SSPL USDA-NRCS Flagstaff Soil Survey Office 1615 S. Plaza Way Flagstaff, AZ 86001 928-214-0421 Ext 102 Fred.Fischer@az.usda.gov	**Cole Mayn** Zoned Soil Scientist Tongass National Forest, Craig Ranger District 907-826-1621 Colemayn@fs.fed.us
James Gordon SSPL USDA-NRCS 4400 Buffalo Gap Road Suite 3600 Abilene, TX 79606-4904 325-692-8238 James.Gordon@tx.usda.gov	**Jim Weigand** Ecologist Bureau of Land Management California State Office 2800 Cottage Way, Room 1928 Sacramento, CA 95825 Phone: James_Weigand@blm.gov

Ed Horn Soil Scientist Bureau of Land Management P.O Box 550 - 3050 NE Third Prineville, OR 97754 541-416-6855 ed_horn@blm.gov	**Eric Wolfbrandt** Soils GIS Specialist USDA-NRCS 3003 N. Central Ave., Suite 800 Phoenix, AZ 85012 602-280-8822 Eric.Wolfbrandt@az.usda.gov
Kent Houston Soil Scientist Shoshone National Forest 808 Meadow Lane Cody, WY 82414 307-578-1242 khouston@fs.fed.us	

7000-05 Advanced Technology in Soil Mapping
Instructor Cadre & Training Design Team

Pete Biggam

Soil Scientist - Soils Program Coordinator, Natural Resources Program Center,
National Park Service, P. O. Box 25287, Lakewood, CO 80109
Phone: 303-987-6948 Fax: 303-987-6704 E-mail: pete_biggam@nps.gov

Education

1979 Bachelor of Science, Forestry, University of Montana

Professional Experience

Mar., 1999 - Present	Soils Program Coordinator, USDOI, National Park Service, Natural Resources Program Center, Lakewood, Colorado Presently serving as the co-chair of the Advanced Technology Committee, National Cooperative Soil Survey
Nov. 1995 – Mar. 1999	Soil Scientist/GIS Coordinator, USDA, Natural Resources Conservation Service, Colorado State Office, Lakewood, Colorado
Mar. 1992 – Nov. 1995	Soil Scientist/Regional GIS Coordinator, USDA, Soil Conservation Service, West National Technical Center, Portland, Oregon
Aug. 1990 – Mar. 1992	Soil Scientist/GIS Specialist, USDA, Soil Conservation Service, Utah State Office, Salt Lake City, Utah
May 1987 – Aug. 1990	Soil Scientist/GIS Specialist, USDA, Soil Conservation Service, National Cartographic and GIS Center, Fort Worth, Texas
Mar. 1980 – May 1987	Soil Scientist, USDA, Soil Conservation Service, Idaho (1st Gooding, then, Coeur d'Alene, and then Lewiston)

Janis Boettinger

Associate Professor of Soil Science and Graduate Program Coordinator
Plants, Soils, and Biometeorology, Utah State University, 4820 Old Main Hill, Logan, UT 84322-4820
Phone: 435-797-4026 Fax: 435-797-3376 E-mail: janis.boettinger@usu.edu

Education

BS	Environmental Technology	Cornell University
MS	Soil Science	University of California, Davis
PhD	Soil Science	University of California, Davis

Professional Experience

1998-Present	Associate Professor of Soil Science (Pedology), Department of Plants, Soils, and Biometeorology (PSB), Utah State University, Logan, UT
1999-2000	Visiting Scientist, Estación Biológica de Doñana, Seville, Spain
1994-Present	Adjunct Associate/Assistant Professor, Department of Geology, Utah State University, Logan, UT
1992-1998	Assistant Professor of Soil Science, PSB, Utah State University, Logan, UT
1988, 1989	Visiting Scientist, CSIRO Division of Soils, Townsville, Queensland, Australia
1985-1991	Graduate Research Assistant, Associate in Teaching, Graduate Teaching Assistant, Department of Land, Air and Water Resources, University of California, Davis.
1984	Soil Scientist, USDA Soil Conservation Service and St. Lawrence County Resource Conservation District, Canton, NY

7000-05 Advanced Technology in Soil Mapping
Instructor Cadre & Training Design Team

Pam Clemmer

Remote Sensing/GIS Specialist, National Science & Technology Center
USDOI-Bureau of Land Management (BLM), Denver Federal Center Bldg. 50, Ste-134, Denver, CO 80109
Phone: 303 236-0824 E-mail: Pam_Clemmer@blm.gov

Education

Cartography, Geography Degree	Kansas State University
Cartography, Geography Degree	Emporia State University

Professional Experience

1990- Present BLM - National Science & Technology Center - Remote Sensing/GIS
1989-1990 BLM - Service Center - Cartographer
1987-1989 Intergraph Corporation, Huntsville Alabama - Senior Systems Engineer
1975-1985 Defense Mapping Agency Aerospace Center, St. Louis, Missouri - Cartographer

Other Interests:
I used to have other interests but now all I do is work and laundry

Nephi J. Cole

Soil Scientist, Buffalo Wyoming Soil Survey Project Office
USDA Natural Resources Conservation Service, 760 West Fetterman, Buffalo, WY 82834
Phone: 307-684-2526 ext. 118 E-mail: nephi.cole@wy.usda.gov

Education

2002-Present	Master of Science (TBC), Utah State University, Logan, UT Soil Science; emphasis Geographic Information Systems (GIS) & Remote Sensing (RS)
1999-2002	Bachelor of Science, Utah State University, Logan, UT Environmental Soil & Water Science (soil emphasis); minors in Geology & Agronomy
1994-1998	Associate of Arts and Science, BYU-Idaho (Ricks College), Rexburg, ID Crop and Soil Science emphasis

Professional Experience

May 2001 – Present	Soil Scientist, USDA Natural Resources Conservation Service, Wyoming
Oct. 2001 – May 2003	Graduate Assistant/ Data Entry, Utah State University, Logan, UT
Sept. 1998 - April 1999	Teachers assistant, Ricks College Agronomy Dept., Rexburg, ID
April-Sept. 1995	Field Person, Stukenholtz Laboratories, Twin Falls, ID

Volunteer Service

Sept. 1995 - Oct. 1997	Missionary/Zone leader, The Church of Jesus Christ of Later-day Saints, Campinas, Brazil

Interests

Technical sport climbing, cycling, shooting sports, fitness, snowboarding, wakeboarding, sports in general, cello, bass guitar

7000-05 Advanced Technology in Soil Mapping
Instructor Cadre & Training Design Team

Pam Clemmer

Remote Sensing/GIS Specialist, National Science & Technology Center
USDOI-Bureau of Land Management (BLM), Denver Federal Center Bldg. 50, Ste-134, Denver, CO 80109
Phone: 303 236-0824 E-mail: Pam_Clemmer@blm.gov

Education

Cartography, Geography Degree Kansas State University
Cartography, Geography Degree Emporia State University

Professional Experience

1990- Present BLM - National Science & Technology Center - Remote Sensing/GIS
1989-1990 BLM - Service Center - Cartographer
1987-1989 Intergraph Corporation, Huntsville Alabama - Senior Systems Engineer
1975-1985 Defense Mapping Agency Aerospace Center, St. Louis, Missouri - Cartographer

Other Interests:
I used to have other interests but now all I do is work and laundry

Nephi J. Cole

Soil Scientist, Buffalo Wyoming Soil Survey Project Office
USDA Natural Resources Conservation Service, 760 West Fetterman, Buffalo, WY 82834
Phone: 307-684-2526 ext. 118 E-mail: nephi.cole@wy.usda.gov

Education

2002-Present Master of Science (TBC), Utah State University, Logan, UT
Soil Science; emphasis Geographic Information Systems (GIS) & Remote Sensing (RS)
1999-2002 Bachelor of Science, Utah State University, Logan, UT
Environmental Soil & Water Science (soil emphasis); minors in Geology & Agronomy
1994-1998 Associate of Arts and Science, BYU-Idaho (Ricks College), Rexburg, ID
Crop and Soil Science emphasis

Professional Experience

May 2001 – Present Soil Scientist, USDA Natural Resources Conservation Service, Wyoming
Oct. 2001 – May 2003 Graduate Assistant/ Data Entry, Utah State University, Logan, UT
Sept. 1998 - April 1999 Teachers assistant, Ricks College Agronomy Dept., Rexburg, ID
April-Sept. 1995 Field Person, Stukenholtz Laboratories, Twin Falls, ID

Volunteer Service

Sept. 1995 - Oct. 1997 Missionary/Zone leader, The Church of Jesus Christ of Later-day Saints, Campinas, Brazil

Interests

Technical sport climbing, cycling, shooting sports, fitness, snowboarding, wakeboarding, sports in general, cello, bass guitar

7000-05 Advanced Technology in Soil Mapping
Instructor Cadre & Training Design Team

Dr. William (Bill) Effland

Soil Scientist/ Landscape Analysis

USDA Natural Resources Conservation Service, 1400 Independence Ave. SW, Washington D.C. 20250

Phone: 202-720-6370 E-mail: william.effland@usda.gov

Education

1990	Ph.D. Soil Morphology and Genesis, Iowa State University "Genesis of Clayey Sediments and Associated Upland Soils Near the Upper Iowa River, Northeast Iowa" (Dissertation Abstract #91-00427) Graduate Advisor: Dr. Thomas E. Fenton
1986	M.S. Soil Morphology and Genesis, Iowa State University, "Spatial Variability of Clarion Soils in Central Iowa" Graduate Advisor: Dr. Thomas E. Fenton
1983	B.S. Agriculture - Plant and Soil Sciences, West Virginia University, Advisor: Dr. Everett M. Jencks

Professional Experience

Jan. 2003 to Present	USDA Natural Resources Conservation Service, Soil Survey Division Research and application of soil landscape mapping technologies such as SoLIM; examination of innovative technologies such as Internet-based delivery of soil survey information; and collaboration with universities and other agencies (e.g., BLM, NPS, USDA-FS) for updating or completing soil resource inventories.
Nov. 1999- Jan. 2003	Soil Scientist, USDA Natural Resources Conservation Service, Resource Assessment Division
June 1993 – Nov. 1999	Environmental Scientist (Senior in 1998), U.S. Environmental Protection Agency, Office of Pesticide Programs, Environmental Fate and Effects Division, Environmental Risk Branch II, Arlington, VA
Dec. 1990 – June 1993	Environmental Soil Scientist, CDM Federal Programs Corporation (CDM Federal), Fairfax, VA
June 1986 – Dec. 1990	Research Associate, Laboratory Manager - ISU Soil Characterization Laboratory, Department of Agronomy, Iowa State University (ISU), Ames, IA.

Other Experience

Aug. 1996 – Present	Assistant Professor (Visiting until becoming Adjunct in June 1997), Department of Geography and Environmental Systems, University of Maryland Baltimore County, 1000 Hilltop Circle, Baltimore, MD
Currently	USDA Graduate School, Evening Programs
Jan. 2003 to Jan. 2006	Associate Editor for Computer Software – *Agronomy Journal*
Author	Various publications (ask Bill for more information on this)

7000-05 Advanced Technology in Soil Mapping
Instructor Cadre & Training Design Team

Earl D. Lockridge

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USDA Natural Resources Conservation Service
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Education:
B. S. Degree - Agricultural Education - Kansas State University
M. S. Degree - Soil Genesis and Morphology - Iowa State University

Professional Experience:

1987-1994	Soil Scientist - Quality Assurance Staff - NSSC - Lincoln, NE Coordination of all training within the Soils Division Includes course development, course coordination, and training needs assessment.
1984-1987	Assistant State Soil Scientist – Minnesota
1977-1984	Project Leader - IN and MO
1974-1977	Project Member – IA

William G. Ypsilantis

Soil Condition and Health Specialist, National Science & Technology Center
USDOI-Bureau of Land Management (BLM), Denver Federal Center Bldg. 50, Denver, CO 80109
Phone: 303-236-3404 Fax: 303-236-3508 E-mail: bill_ypsilantis@blm.gov

Education

1975	Master of Science, Forest Soils, University of Idaho
1967	Bachelor of Science, Forest Management, Michigan Technological University

Professional Experience

Feb. 2001 – present	Soil Health and Condition Specialist, National Science and Technology Center, USDOI- BLM, Denver, CO
Jan. 1987 – Feb. 2001	District Soil Scientist, USDOI-BLM, Coeur d'Alene, ID
Jan. 1979 – Jan. 1987	District Soil Scientist, USDOI- BLM, Montrose, CO
Oct. 1976 – Jan. 1979	Soil Scientist, USDOI- BLM, Winnemucca, NV
Feb. 1970 – Jun. 1072	Municipal Forester, City of Detroit, Detroit, MI

COURSE OVERVIEW

Advanced Technology in Soil Mapping

Introduction

Soil Mapping Program Goal

Through innovative and efficient use of advanced technologies,

produce and deliver to customers high quality, dynamic, accessible soil information that meets the standards of the National Cooperative Soil Survey.

Course Goal

Participants will effectively apply concepts of digital mapping using appropriate technology & resources to enhance soil mapping techniques, data evaluation, and product delivery

Advanced Technology

The use of advanced technology in soil survey provides value-added products for our customers as a result of:

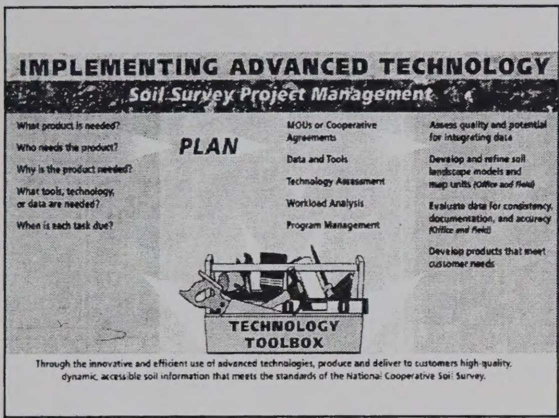
- integrating digital data
- performing landscape modeling
- using analysis to capture and record knowledge of soil-landscape relationship
- establishing repeatable mapping processes
- using technology to improve map efficiency and accuracy

Course Overview

- ✓ Concepts of advanced technology
- ✓ Advanced technology tools
- ✓ Exercises for each major topic
- ✓ Final summation exercise
- ✓ Course evaluation

Major Topics

- ❑ Planning
- ❑ Project management
- ❑ Integrating data
- ❑ Developing maps
- ❑ Evaluation
- ❑ Product development
- ❑ Final case study



IMPLEMENTING ADVANCED TECHNOLOGY
Soil Survey Project Management
What product is needed?
Who needs the product?
Why is the product needed?
What tools, technology, or data are needed?
When is each task due?
PLAN
MOUs or Cooperative Agreements
Data and Tools
Technology Assessment
Workload Analysis
Program Management
Assess quality and potential for integrating data
Develop and refine soil landscape models and map units (Office and Field)
Evaluate data for consistency, documentation, and accuracy (Office and Field)
Develop products that meet customer needs
TECHNOLOGY TOOLBOX
Through the innovative and efficient use of advanced technologies, produce and deliver to customers high-quality, dynamic, accessible soil information that meets the standards of the National Cooperative Soil Survey.

Advanced Technology

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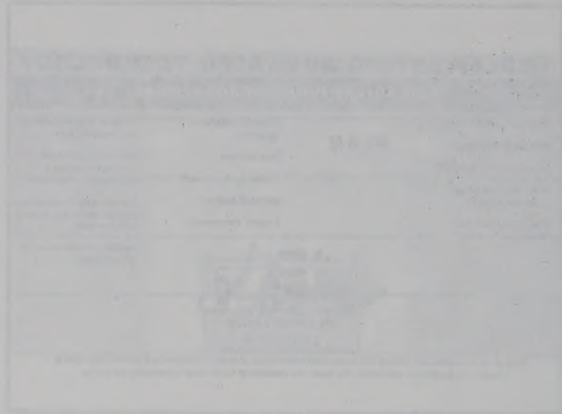

Course Overview

- Compare conventional technology
- Advanced technology tools
- Exercises for each major topic
- Final summation exercise
- Course evaluation

Major Topics

- Planning
- Project management
- Integrating data
- Developing maps
- Evaluation
- Product development
- Final case study

PLANNING

Truisms for Life…

and Planning

People do not plan to fail…

they just fail to plan

Plan ahead…

It wasn't raining when Noah built the ark!

A goal properly set is…

halfway reached

A goal without a plan…

is just a wish

Planning the Soil Survey

Objectives

- Evaluate a customer agreement (such as a Memorandum of Understanding) to determine if it addresses scope of project, customer expectations, and stakeholder responsibilities
- Identify customers and organize focus sessions to determine soil survey information and product needs

7

Assessing User Needs

- Data Rich, Information Poor
- Data & Information aren't synonyms, but they are strongly related
- Data is of no value until it does somebody some good (information).

8

The Need

Goal of soil survey is to ensure:

1) current & accurate soil information in a useable format

and

2) up-to-date database that <u>meets the information needs of the majority of customers</u>.

9

THE PROCESS

(NSSH 610.04)

- A major step in the planning process for a soil survey project involves gathering information about the needs of the customers.
- True of all soil surveys.

10

The Players

11

"The focus of the National Cooperative Soil Survey is to **TEAM with partners** in the development, acquisition, & dissemination of soil quality information and technology to **HELP PEOPLE** conserve & sustain our natural resources & the environment."

12

USING ADVANCED TECHNOLOGY

- Break out of our perceptions of what customers need
- **Learn to think beyond ourselves "out of the box"**
- **Be willing to listen**
- **Let customer needs drive what we provide**
- **Be equally "information-minded" & "data-minded."**

13

Assessing User Needs

To Focus On Information (user) Needs,
We Must First Identify
Just Who Is Our Customer?

- Many will be the same customers as in the past
- Some will be new
  - o Direct requests
  - o Revealed in information requests through our agency channels, at both Field & SO level

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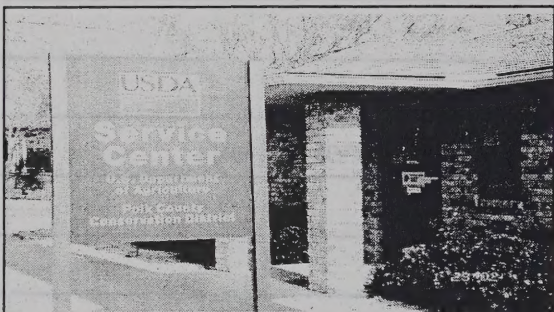
Exercise

Who are our customers?

15

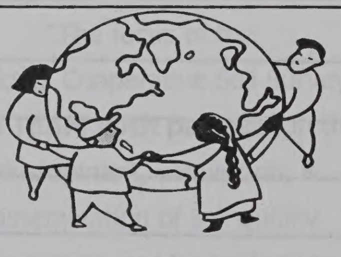
Two Categories

16



Internal

17



EXTERNAL

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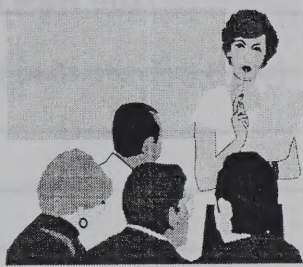
Today, our customers reflect a broad spectrum of people, organizations, businesses, & other entities.



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And Now

Using advanced technology,

we have the flexibility to tailor

their information according to

their specific needs.

20

Methods and Tools

- Focus Groups
  - Internal
  - External
- Information Meetings
- Requests for Information

21

Focus Group Meeting Preparation

What steps do we need to take in preparing for focus group meeting?

22

Additional Thoughts:

✓ **Not every need can be addressed**

✓ **Continual needs assessment must be conducted throughout the project**

23

Next Step

Development of:

- ❑ Memorandum of Understanding
- ❑ Cooperative Agreements
- ❑ Funding Agreements
- ❑ Other types of agreements

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NSSH Part 607

- Memorandum of Understanding (MOU)
- Map products
- Reference materials

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MOU

Prepared by:

State Soil Scientist or lead cooperator with review of others cooperating to complete the survey

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Memorandum of Understanding (MOU)

27

What Is a Memorandum of Understanding?

- Records responsibilities & specifications for conducting the soil survey
- Working agreement developed on the basis of an understanding of cooperative work with other agencies & organizations
- Not a contract

Cooperative Agreements are contracts!!

28

Why is a MOU Important?

- Provides written guidance to cooperators and partners
- May provide for other work agreements
- Formal signed document of intent by <u>all participating cooperators</u>

29

Why Is a MOU Important?
continued

- Records decisions made about the intent of the survey, data needs, interpretations, special investigations, products, etc. <u>for guiding the project leader</u>
- <u>Required</u> for all initial and update soil survey projects

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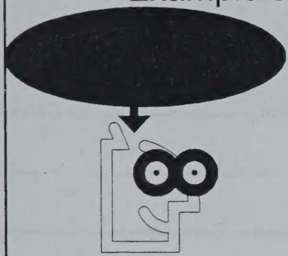
Example of an MOU



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MOU

- Purpose
- Previous publications
- Description of work area
- Roles and functions of cooperators

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MOU Specifications

- Map unit design
- Documentation
- Studies
- Lab analysis
- Maps

33

MOU Specifications
continued

- Approximate time schedule
- Publication
- Advance Information
- Old mapping

34

IS THAT ALL THERE IS???

Amendments required!

What if things change? *LIKE...*

1. **Area to be mapped**
2. **Purpose for doing the survey**
3. **Specific plans for publishing the survey**
4. **Specifications for map scale or format or text format**

35

Summary

- **MOUs are written so that every cooperator knows exactly what is expected.**
- **MOUs should be simple, clear and concise.**

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UNITED STATES DEPARTMENT OF AGRICULTURE

NATIONAL COOPERATIVE SOIL SURVEY

MEMORANDUM OF UNDERSTANDING

between

THE NATURAL RESOURCES CONSERVATION SERVICE

BUREAU OF LAND MANAGEMENT

BETA COUNTY SOIL AND WATER CONSERVATION DISTRICT

and

BETA AGRICULTURAL EXPERIMENT STATION

relative to

THE MAKING OF A SOIL SURVEY FOR

JUNIPER DRAW QUAD, ALPHA COUNTY, WY

NT001

Authority

Public Law 74-46, 49 Stat. 163 (16 U.S.C. 590 a-f) and Public Law 89-560, 80 Stat. 706 (42 U.S.C. 3271-3274).

Purpose for Doing the Work

The purpose of this survey is to provide soil data necessary to judiciously and efficiently manage land for agriculture and for rural and community development and to understand, protect, and enhance the environment. The soil survey will be used specifically for the management of cropland, pasture, wildlife habitat, rangeland, and irrigation development; for the identification of important farmlands, hydric soils, and highly erodible land; for the equalization of farmland assessments; and to estimate engineering properties of the soils. Interpretations for land application of water will be generated for all arable map units.

The soil data will be used by the county commissioners, the Experiment Station, the Extension Service, the Federal Crop Insurance Corporation, private landowners, managers of forestland, rangeland, and fish and wildlife habitat, farmers, and ranchers. Private land in the county is managed primarily for irrigated agriculture and rangeland.

Previous Publications

In 1963 a general soil map of Alpha County was published by the Agricultural Experiment Station, Beta State University (1). In 1968 Bulletin No. 499, Soil Survey Report County General Soil Maps, Beta State, were published (2). The survey described in this memorandum will display the soils in more detail and provide information and interpretations not included in the 1963 General Soil Map of Alpha County and the 1968 Bulletin No. 499.

Description of the Work Area

Alpha County is located in southeastern Beta State. The county has a total area of 1,149,739 acres, of which 1,141,87 acres is land and 2,868 acres is water areas equal to or more than 40 acres in size. The land acres include water areas that are less than 40 acres in size. The county is bounded by Lambda County on the east, by Sigma County on the north, by Gamma county on the west, and by Epsilon County on the south. The land ownership in the county is 81 percent private and state and 19 percent Federal. The Federal land is primarily held as small contiguous areas of 25,000 to 50,000 acres with many smaller tracts of less then 1,000 acres surrounded by private/state land.

The land use in 2001 was as follows: cropland, 6 percent; rangeland and pastureland, 93 percent; and forest and other land, 1 percent (3).

About 95 percent of the survey area is in the Alpha Level Plains Major Land Resource Area, and the remaining 5 percent is in the Dark Morainic Hills of the Great Alpha and Gamma Region.

The dominant landforms in the county are rolling bedrock-controlled hills, alluvial fans, floodplains, and stream terraces. A small area of foothills and mountains occurs in the western part.

Cooperating Agencies and Responsibilities

The Natural Resources Conservation Service, the Bureau of Land Management, the Beta Agricultural Experiment Station, and the Beta County Soil Conservation District will cooperate in the conduct of this soil survey in accordance with their respective memorandums of understanding or contribution agreements and with dependence upon annual appropriations. The governing documents that

identify the cooperating agencies and their areas of responsibility are: (1) the Memorandum of Understanding between the Natural Resources Conservation Service, United States Department of Agriculture and the Bureau of land Management, United State Department of the Interior relative to making and using soil surveys.

The Natural Resources Conservation Service will provide a project staff to complete the field mapping by about December 2004. The Natural Resources Conservation Service will provide base maps for fieldwork and publication, equipment, supplies, and transportation. The Natural Resources Conservation Service will also provide the quality control necessary to meet the National and Alpha Cooperative Soil Survey standards as enumerated in the National Soil Survey Handbook and the Beta state supplements. The Natural Resources Conservation Service has the responsibility for preparation of the final maps, which will be done by soil scientists. The Natural Resources Conservation Service project office will report all progress promptly and keep progress records and maps current.

Bureau of Land Management will provide additional resource staff to assist with collection of data relative to rangeland condition, productivity, quality, and will assist in developing interpretations which meet the identified customer needs for the management of rangeland throughout Beta county.

The Beta Agricultural Experiment Station will cooperate in the conduct of the soil survey by providing laboratory assistance, thrashing grain samples and calculating yields and productivity indexes, participating in field reviews, and providing technical assistance in the review and preparation of special sections of the soil survey publication.

The Beta County Soil and Water Conservation District will provide liaison and publicity to private landowners, especially those in difficult access areas, and provide leadership for a "First Acre Mapped" and a "Last Acre Mapped" ceremony. They will also provide office space to house the soil survey staff. A contribution agreement is anticipated between the Beta County Soil Conservation District and the Natural Resources Conservation Service for use of funds provided by the Beta County Board of Commissioners.

Specifications

pasture sections respectively. They will also help in technical review of the document. The preliminary and final interpretation tables will be generated from NASIS database files. The soil survey project leader and staff will review them and changes will be suggested to the MLRA office as needed. The soil survey will be distributed and explained to the public as detailed in the Beta state plan.

Advance Information

Advance information will be provided to users upon request or in accordance with contributing agreements. All advance information will conform to the specifications itemized in the National Soil Survey Handbook.

Old Mapping

In previous years 2000 acres of the Juniper Quad were mapped mostly for conservation planning on individual farms. This old mapping will be used to the extent possible. Every effort will be made to maintain the existing soil boundaries of this old mapping; however, where the boundaries are inappropriate they will be changed. These acres will be reported as Updated Soil Survey Progress Code 185.

Approval

The signing of this memorandum cancels all previous soil survey work plans or memoranda of understanding for Alpha County, Beta State.

Reference

1. General Soil Map, Alpha County, 1963 published by the Agricultural Experiment Station, Beta State University, Casper, Wyoming.
2. Soil Survey Report, Bulletin 499, by D.D. Alpha, G.A. Beta, M.D. Gamma, and H.W. Sigma, Department of Soils, Agricultural Experiment Station, Beta State University, July 1968.
3. Beta Conservation Needs, Natural Resources Conservation Service, Casper, Wyoming, July 1970.
4. Beta State Agricultural Statistics 1986, USDA Economics and Statistics Service and Beta State University, Agricultural Experiment Station.

Activities conducted under this Memorandum of Understanding will be in compliance with the nondiscrimination provisions as contained in the Titles VI and VII of the Civil Rights Act of 1964, as amended, the Civil Rights Restoration Act of 1987 (Public Law 100-259) and other nondiscrimination

statutes, namely Section 504 of the Rehabilitation Act of 1973, Title IX of the Education Amendments of 1972, the Age Discrimination Act of 1975, and in accordance with regulations of the Secretary of Agriculture (7CFR-15, Subparts A and B) which provide that no person in the United States shall on the grounds of race, color, national origin, age, sex, religion, marital status, or handicap be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity receiving Federal financial assistance from the Department of Agriculture or any agency thereof.

A.J. Jones
State Conservationist
Natural Resources Conservation Service
Date______________________

____

W.F. White
Chairperson
Alpha County Soil
Conservation District
Date______________________

____

C.J. Smith
Director
Beta Agricultural Experiment Station
Date______________________

____

Work Load Analysis

Project Management

Objectives

For a given project & using a work load analysis template:

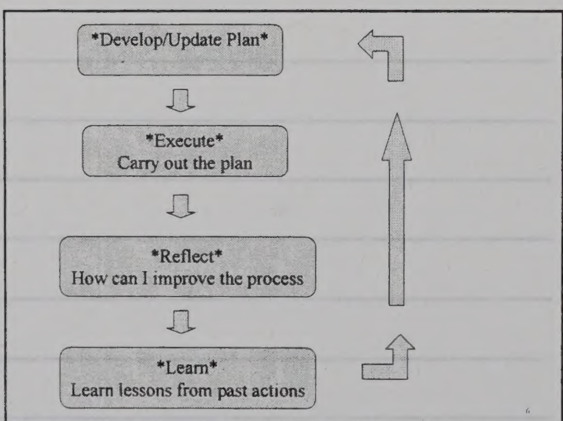
- Develop a Work Load Analysis that addresses the goals, staff needs, timelines, and tasks to complete a soil survey that meets the customer agreement requirements
- Identify the tools and kinds of data needed to make the most use of advanced technologies for completion and distribution soil survey products.

Proactive People

Do the right things on time

Planning means...

You keep EVERYONE informed
about
when tasks will be completed



NSSH Part 608.05 Determining Work Loads

- Listing the work to be done
- Estimating time to complete each task
- Providing a timetable for completing work
- Exhibit 608-1

NSSH Part 608.07 Planning Work Flow

- Identifies activities given in the work load analysis that are to be accomplished during the given time period covered by the plan
- Includes
  - Who is responsible for each activity
  - Project's completion dates
  - Project's goals
  - Exhibit 608-2

Will a WLA & Plan save you time?

- Analysis & planning up front saves time later
- It more than pays for itself, **IF YOU USE IT** (stay focused on your goals)

Our WLA has 4 major variables

- Length of time
- Number of staff
- Tasks to be performed (acreage, map unit, etc.)
- Rates of productivity

Use any of these variables to complete an analysis that results in recommended staff = assigned staff

10

The 4 variables

- Length of time
  You may or may not have much to say about this
- Number of staff
  You probably don't have much to say about this
- Tasks to be performed
  This is what it is!
- Rates of productivity
  You may have flexibility

11

Gathering Tools

What do we gather?

12

Acquiring Data

What kinds of data would we need to gather to support advanced technologies for our project?

Three Kinds of Data

Hard Copy	• Topographic Maps • Soil Maps • Bedrock Geology Maps • Map Unit Descriptions
Digital	• Digital Elevation Models • Imagery • GIS Coverages
Field Reconnaissance	• Field visits • Photographs • Notes

Our WSA has 4 major variables

The 4 variables

Gathering Tools

What do we collect?

SOIL FORMING FACTORS

Soil Formation

Factors of Soil Formation
(Hans Jenny, 1941)

Conceptual model of soil formation
$S = f(Cl, O, R, P, T\ldots)$

Can be used to predict distribution of soils on the landscape:
Guiding principle in Soil Survey

S = f (Cl, O, R, P, T…)

Soil (S) is a function of:

- Climate - amount, seasonality of precipitation, temperature
- Organisms - primarily vegetation
- Relief or Topography - slope, aspect, landscape position
- Parent Material - organic or mineral; composition, constitution of rock, deposit
- Time - soil or landform "age"

Soil Forming Factors Influence Pedogenic Processes

- Climate: Temperature, precipitation control rates of chemical weathering, leaching
- Organisms: Vegetation dictates rate, mechanism of organic C input
- Relief: Slope influences erosion rate
- Parent material: Rock composition influences weathering reactions possible
- Time: Reflects stability of geomorphic surface

Soil Forming Factors

$S = f\,(Cl, O, R, P, T)$

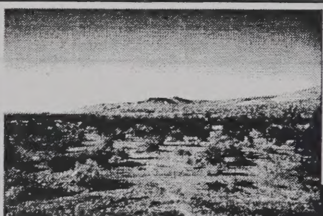
Independent Factors?

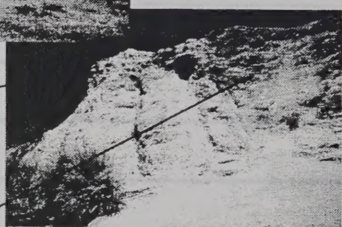
$S = f\,(P)_{Cl,\,O,\,R,\,T}$

$S = f\,(R)_{Cl,\,O,\,P,\,T}$

P
Parent Material

Residuum on Granitic Pediments, W Mojave Desert



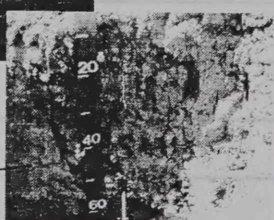


Granodiorite = Haplodurids

Quartz Monzonite = Haplargids

R
Relief

Chinle fm, Circle Cliffs, UT



Badlands

Fine Ustertic Haplargids

Soil Forming Factors

S = f (Cl, O, R, P, T)

Factors co-vary

-Vegetation (O) vary with climate (Cl), e.g., orographic climate, life zones vary w/elevation

-Parent material (P) dictate vegetation (O), e.g., serpentine supports unique vegetation

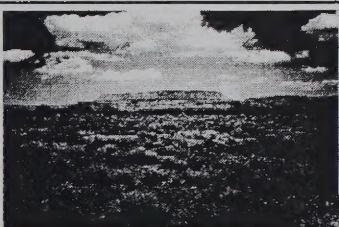
Factor-soil feedbacks

-Vegetation restricted by soil properties, e.g., depth, duration of saturation, alkalinity

Factor-soil feedbacks

Moenkopi Fm
Circle Cliffs, UT

<u>Loamy-skeletal</u>
Lithic Ustic Torriorthents
support
pinyon-juniper

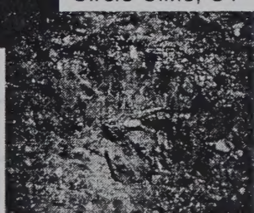


Factor-soil feedbacks

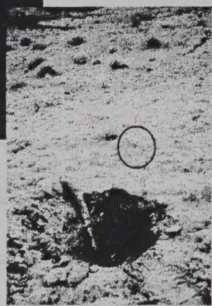
Moenkopi fm
with <u>eolian cap</u>
Circle Cliffs, UT

<u>Loamy</u>
Lithic Ustic Torriorthents
support
grasses, forbs, shrubs

Vegetation influence fire regime, perpetuates vegetation?



Factor-soil Feedbacks



Loamy-skeletal, gypsic
Lithic Torriorthent

Summerville fm (upper Jurassic)
rare plant habitat

Castle Valley, UT

Soil Forming Factors

S = f (Cl, O, R, P, T)

KEY: Unique sets of factors produce unique soils on the landscape

These relationships can be quantified

Soil Forming Factors

S = f (Cl, O, R, P, T)

COROLLARY: Unique sets of factors produce unique soils on the landscape that have unique use and management

Relationships between soils, factors, interpretations can also be quantified

Soils and Soil Forming Factors

Influence Interpretations for Land Use, e.g.,

- Steep slopes, shallow soils
  - Less stable
  - High erosion rates
- Young soil, no rock fragments, low slope
  - High available water capacity
  - Highly productive agricultural land
- Gypsiferous shales, shallow gypsum-rich soils
  - Habitat for rare, endemic plants

Soil Formation: Advanced Technology

- Conceptual model of soil formation

  S = f (Cl, O, R, P, T...)
- Find spatially explicit, digital data that proxy for one or more soil forming factors
- Quantify model of soil formation, test in field, refine
- Update as needed
  - Changing land uses
  - Additional data available

MAPPING -
INTEGRATING DATA

Mapping - Data Integration

Applying the concepts of soil formation, assess the quality and potential to integrate digital data into the mapping process.

Understanding the Data

- Soil Forming Concepts
- Current Technologies
- Spatial Data
- Datums and Projections
- Metadata
- Remote Sensing Review
- Preprocessing

Mapping Techniques

- Manual mapping on hardcopy overlays
- Manual mapping in a digital environment
- Automated mapping using rule-based classifiers

Integrating Data

- Aligning data in geographic space
- Merging data for visual interpretation
- Performing spatial analysis

Current Geospatial Technology

- ESRI Products
  - ArcView3.x
  - ArcGIS
- ERDAS Imagine
- 3DMapper
- USDA - Soil Data Viewer
- USFS - TEUI Toolkit

Determine Data Requirements

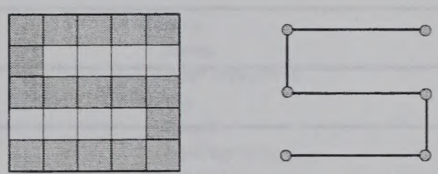
Don't let the technology drive the application!!

- Elevation
- Temperature
- Climate - Arid/Semi-arid
- Vegetation cover
- Landform
- Geology
- Pre-existing soils information

Data Availability

- Internet Availability
- Interagency Data Sharing
- Interagency Partnerships
- Commercial Availability

Geospatial Data Types



Raster
- Cell
- Pixel
- Grid

Vector
- Points
- Lines
- Polygons

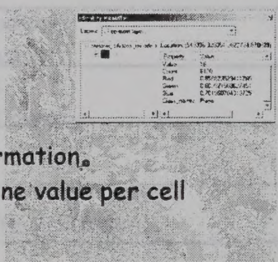
Raster Data

- Continuous
- Thematic

Continuous Raster Data

- Quantitative (elev/temp/reflectance)
- May have one or more layers

Thematic Raster Data

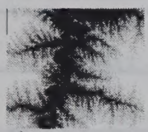


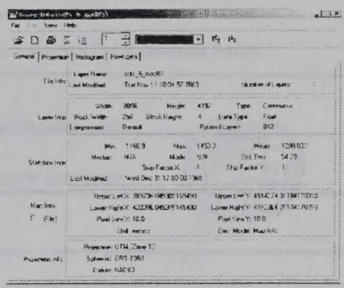
- Categorical information.
- One-layer with one value per cell

Raster Data Examples

- Continuous
  - Satellite
  - Digital Ortho Quadrangles (DOQ)
  - Scanned Aerial Photography
  - Digital Elevation Model (DEM)
- Thematic
  - Landcover

Digital Elevation Models

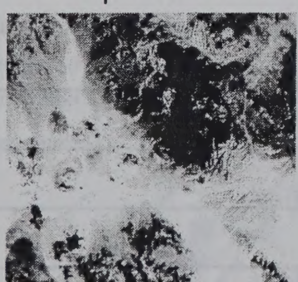




Vector Data

- Points
  - Cities
  - Spot elevations
- Lines
  - Roads
  - Hydrography
- Polygons
  - Soils
  - Vegetation

Geospatial Data



What is a datum?

A point, line, or surface used as a reference.

Maps are referenced to a horizontal and a vertical datum

Horizontal Datum

Mapped by the Army Map Service
Published for civil use by the Geological Survey

Control by USGS, NOS/NOAA and USCE

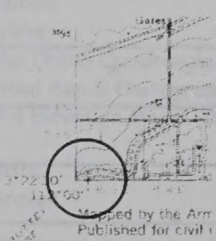
Topography by photogrammetric methods from aerial photographs taken 1951. Field checked 1952

Polyconic projection. 10,000-foot grid ticks based on Arizona coordinate system, central zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue. 1927 North American Datum
To place on the predicted North American Datum 1983 move the projection lines 2 meters south and 65 meters east as shown by dashed corner ticks

Red tint indicates area in which only landmark buildings are shown

There may be private inholdings within the boundaries of the National or State reservations shown on this map

NAD 1983 Datum Ticks

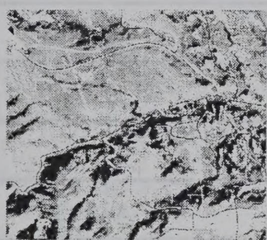


Horizontal Datums

- NAD 1927 - referenced from Meades Ranch, Kansas
- NAD 1983 - earth centered
- WGS 1984 - earth centered

Why is understanding the horizontal datum important?

Map features do NOT match from one datum to the other because they are referenced from different points.



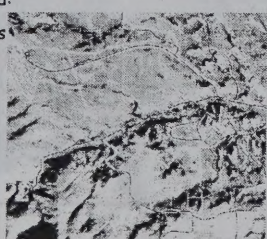
Other Data Registration Problems

Notice red roads do not always match image features

Data may have been collected:

-From different data sources

-From different dates



Projection/Coordinates

Mapped by the Army Map Service
Published for civil use by the Geological Survey

Control by USGS, NOS/NOAA and USCE

Topography by photogrammetric methods from aerial photographs taken 1951. Field checked 1952

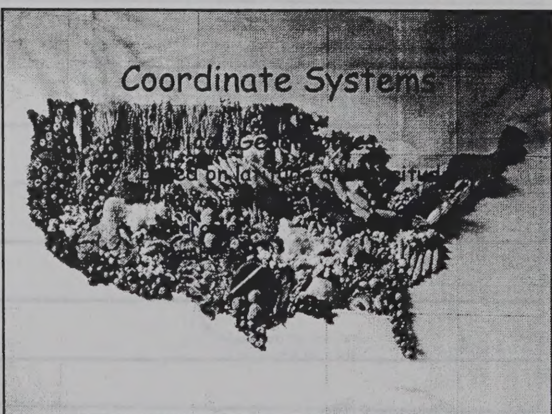
Polyconic projection. 10,000-foot grid ticks based on Arizona coordinate system, central zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue. 1927 North American Datum
To place on the predicted North American Datum 1983 move the projection lines 2 meters south and 65 meters east as shown by dashed corner ticks

Red tint indicates area in which only landmark buildings are shown

There may be private inholdings within the boundaries of the National or State reservations shown on this map

How many Coordinate Systems are on the map?

- Geographics
- Universal Transverse Mercator
- State Plane



Spherical Projection

Mapped by the Army Map Service
Published for civil use by the Geological Survey

Control by USGS, NOS/NOAA and USCE

Topography by photogrammetric methods from aerial photographs taken 1951. Field checked 1952

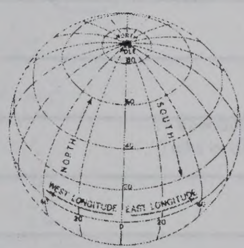
Polyconic projection. 10,000-foot grid ticks based on Arizona coordinate system, central zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue. 1927 North American Datum
To place on the predicted North American Datum 1983 move the projection lines [illegible] meters south and 65 meters east as shown by dashed corner ticks

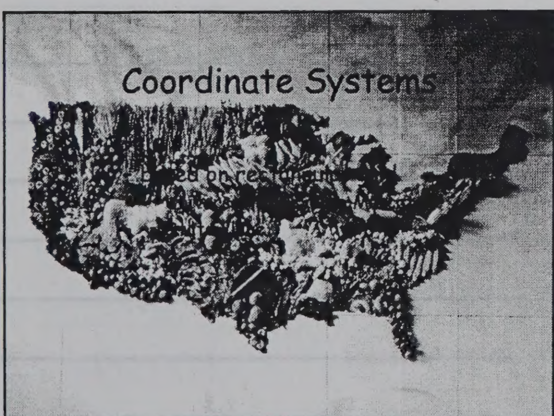
Red tint indicates area in which only landmark buildings are shown

There may be private inholdings within the boundaries of the National or State reservations shown on this map

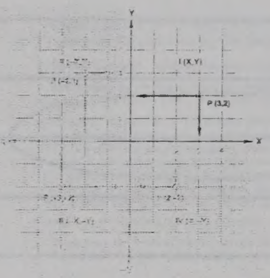
Spherical Coordinates

- Degrees
- Minutes
- Seconds





Cartesian Coordinates



- Meters - UTM
- Feet-State Plane

UTM Projection

Mapped by the Army Map Service
Published for civil use by the Geological Survey

Control by USGS, NOS/NOAA and USCE

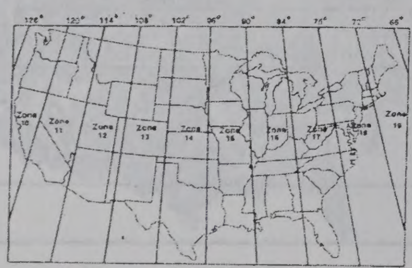
Topography by photogrammetric methods from aerial photographs taken 1951. Field checked 1952

Polyconic projection. 10,000-foot grid ticks based on Arizona coordinate system, central zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue. 1927 North American Datum
To place on the predicted North American Datum 1983 move the projection lines 2 meters south and 65 meters east as shown by dashed corner ticks

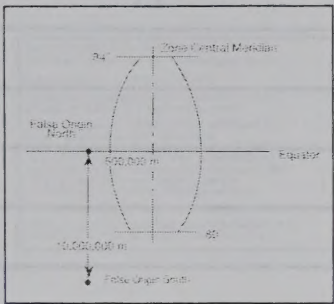
Red tint indicates area in which only landmark buildings are shown

There may be private inholdings within the boundaries of the National or State reservations shown on this map

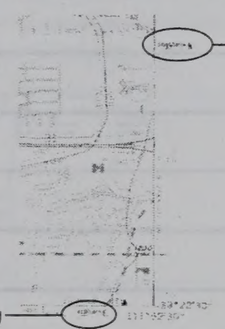
Universal Transverse Mercator Grid Zones



UTM Grid Zone



UTM Grid Labeling

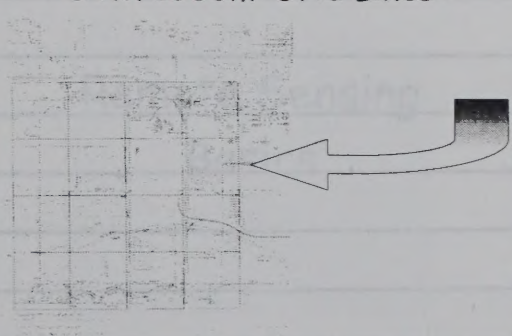


Y = Northing

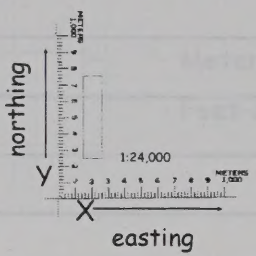
XY Coordinates
Ticks in blue

X = Easting

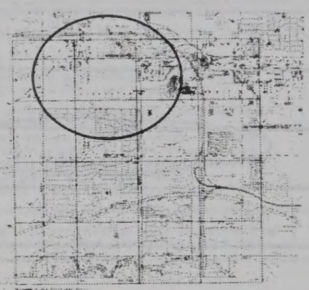
UTM 1000m Grid Lines



UTM 1,000 Meter Grid



Reading a UTM Coordinate

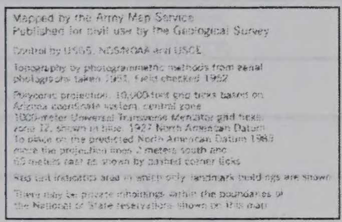


Metadata

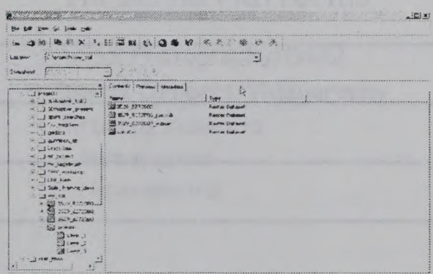
"Data about Data"

Describes the content, quality, condition, and other characteristics of data

Hardcopy Metadata

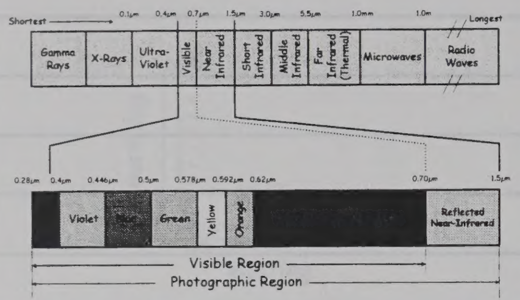


Digital Metadata in ArcCatalog

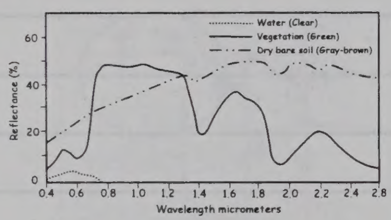


Remote Sensing Basics

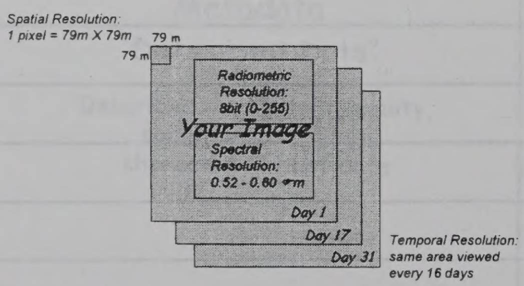
The Electromagnetic Spectrum



Spectral Reflectance Curves



Four Types of Resolution



Satellite Platforms

Higher Spatial Resolution

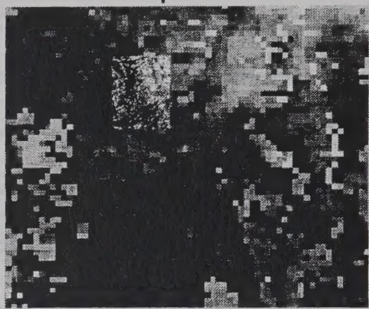
- AVHRR
- MODIS
- ASTER
- Landsat
- SPOT
- IKONOS
- Quickbird

Airborne Platforms

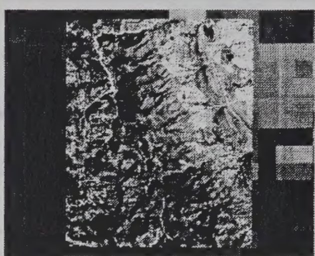
- Aerial Photography/DOQ
- Digital Cameras/Videography
- Airborne scanners
  - Multispectral
  - Hyperspectral

AVHRR 1.1km

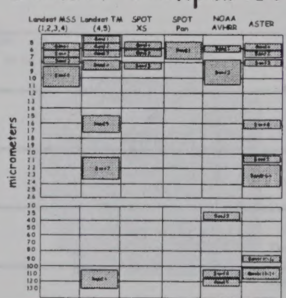
AVHRR 1.1km/Landsat 30m Comparison



Landsat 30-meter



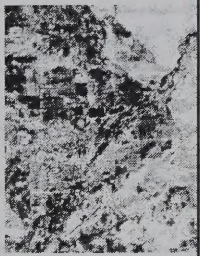
Sensor Comparison



Landsat Imagery

Thematic Mapper (TM)
7 bands
- 6 bands multispectral, 30m resolution
- 1 band thermal, 120m resolution

Enhanced Thematic Mapper (ETM)
8 bands
- 6 bands multispectral, 30m resolution
- Thermal, 60m resolution
- Panchromatic, 15m resolution



Thematic Mapper Band Characteristics

1 = Blue, 0.45-0.52μm
Useful for mapping coastal water areas, differentiating between soil and vegetation, forest type mapping, and detecting cultural features.

2 = Green, 0.52-0.60μm
Corresponds to the green reflectance of healthy vegetation. Also useful for cultural feature identification.

3 = Red, 0.63-0.69μm
Useful for discriminating between many plant species. Also useful for determining soil boundary and geological boundary delineations as well as cultural features.

4= Reflective-infrared, 0.76-0.90μm
Especially responsive to the amount of vegetation biomass present in a scene. It is useful for crop identification and emphasizes soil/crop and land/water contrasts.

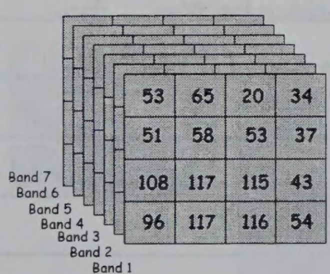
5 = Mid-infrared, 1.55-1.75μm
Sensitive to the amount of water in plants, which is useful in crop drought studies and in plant health analyses. One of the few bands that can be used to discriminate between clouds, snow, and ice.

6 = Thermal-infrared, 10.40-12.50μm
Useful for vegetation and crop stress detection, heat intensity, insecticide applications, and for locating thermal pollution. It can also be used to locate geothermal activity.

7 = Mid-infrared, 2.08-2.35μm
Important for the discrimination of geologic rock type and soil boundaries, as well as soil and vegetation moisture content.

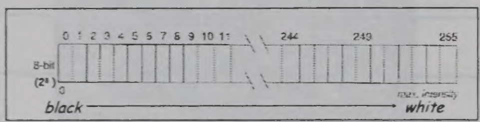
Bands 3, 5 + 7 best for enhancing soil characteristics

Landsat Thematic Mapper Data Layers

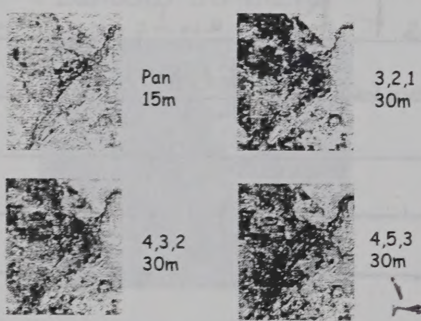


8-bit data (2^8)
Digital Numbers
DN's with spectral values from 0-255

Structure for 8-bit Data



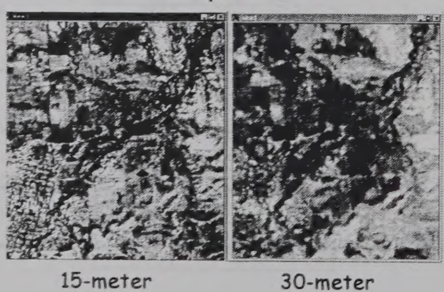
Band Combination Comparisons



best

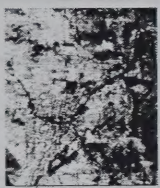
4,5,3 band combination gives good soil info.

Landsat7 Pan and MSS Resolution Comparison

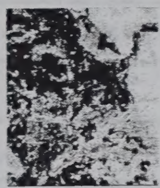


Resolution merge lose spectral resolution for spacial resolution

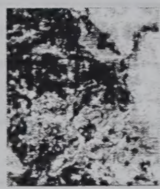
Individual Landsat TM Bands



Band 4
Near IR



Band 3
Red



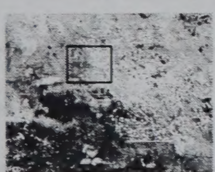
Band 2
Green

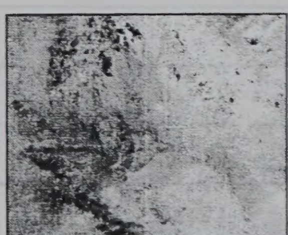
Preprocessing

- Merge
- Resample
- Rectification
- Reproject
- Subset
- Enhancement
- Layerstack

Subset

Creating a smaller area of interest from a larger file



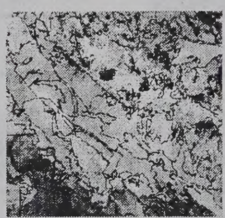


Soil Enhancement Band Ratio Technique

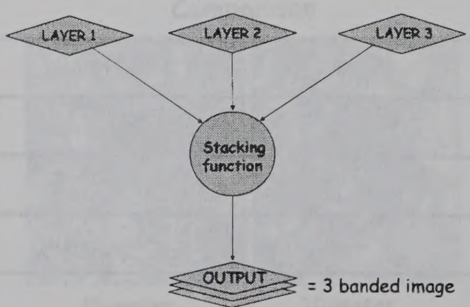
- Proven to be useful in arid climates
- Compensates for shadows, aspect, and atmospheric interference
- Less vegetative cover
- Uses Landsat bands:
  - Band 2; green (0.52-0.60μm)
  - Band 3; red (0.63-0.69μm)
  - Band 5; mid-infrared (1.55-1.75μm)
  - Band 7; mid-infrared (2.08-2.35μm)

Soil Enhancement Ratio

R	G	B
3/2	3/7	5/7



Layerstack

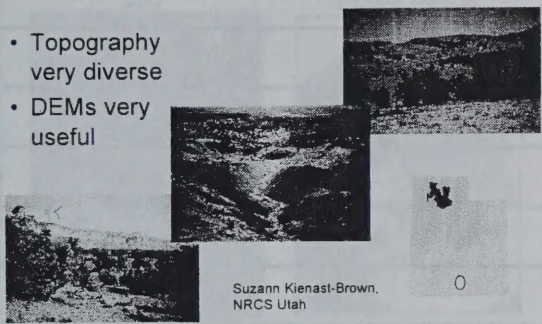


Summary

- Data integration and preparation requires knowledge of:
  - Projections
  - Datums
  - Remote Sensing
  - Preprocessing techniques
  - Use of metadata

Circle Cliffs Area, Grand Staircase-Escalante National Monument

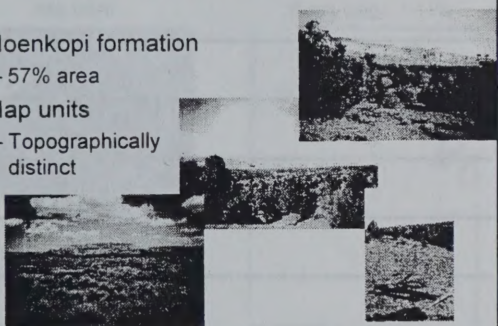
- Topography very diverse
- DEMs very useful



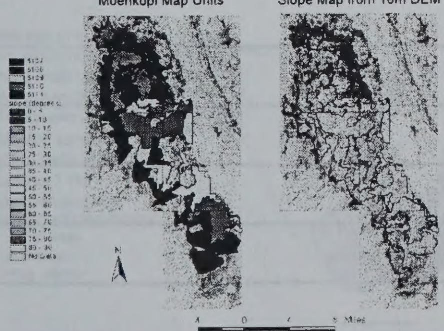
Suzann Kienast-Brown, NRCS Utah

Circle Cliffs

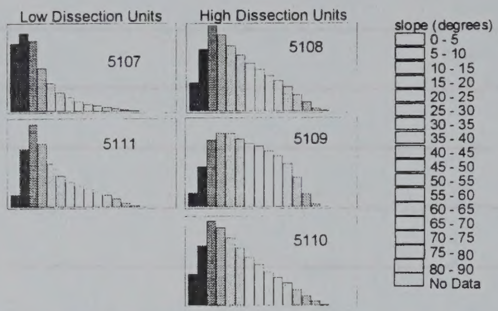
- Moenkopi formation
  - 57% area
- Map units
  - Topographically distinct



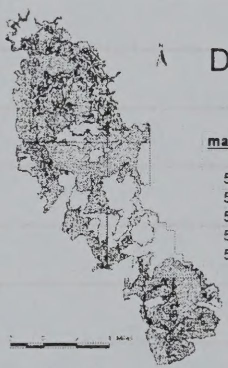
Circle Cliffs



Circle Cliffs: Slope Distribution by Map Unit



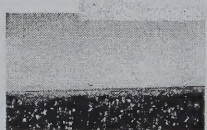
Circle Cliffs: Drainage Density by Map Unit



map unit	% area in drainages
5107	20
5108	26
5109	26
5110	26
5111	24

East Shore Area of the Great Salt Lake

- Update soil survey
- Refine map units with wet and saline components
  - Soil/ecologic
  - Site/hydrologic
- Lake plain sediments
- Very little topography



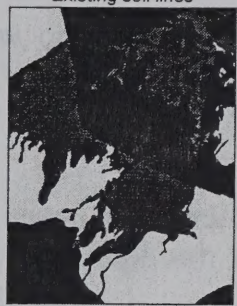
Suzann Kienast-Brown, NRCS Utah

East Shore Area-Great Salt Lake

Available data layers for Mouth of Bear River Quad:

DOQ

Existing soil lines

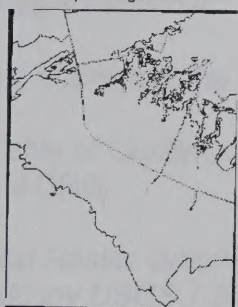


East Shore Area-Great Salt Lake

Only DEM Available:

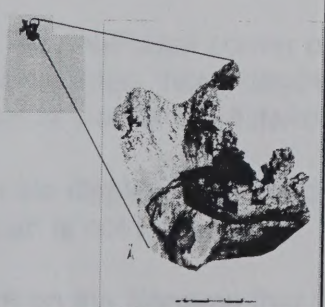
30m DEM

Slope range: 1-11%



East Shore Area-Great Salt Lake

- DEMs <u>not</u> provide information needed for refining map units
  - Resolution (30m)
  - Topography (a joke?)
- Remotely sensed spectral data useful
  - Landsat 7 TM
  - Unsupervised and supervised classification
    - •W et areas
    - •Salt crusts
    - •Veg etation



DATUM EXERCISE

Objective: In this exercise, you will compare a Digital Raster Graphic (DRG) file that has been projected using in different datums (NAD27 and NAD83) and discover how it effects the display of the data.

Viewing Datums in ArcView3.X

1. To open ArcView, double-click on the desktop icon.

2. In the Welcome to ArcView GIS dialog box, click **OK** to Create a new project with a new View.

3. In the Add data dialog box, click **Yes** to add data to the View.
   a. In the **Drives:** dropdown, select the appropriate drive and navigate to the data directory.

   b. From the **Data Source Types:** dropdown menu select **Image Data Source.**

   c. Select mulitiple files by holding the SHIFT key down and click on 044106b2_datum1.tif and o44106b2_datum2.tif. Click **OK**. Both files will be added to the View1 window.

4. Click and drag the corners of the ArcView windows to enlarge the viewing area.

5. In the ArcView Table of Contents, click in the box to display the o44106b2_datum1.tif DRG.

These files are Digital Raster Graphics (DRGs). They were created by scanning and georeferencing hardcopy USGS 7.5-minute quadrangles. They are essentially digital paper maps.

What datum was used to create the original hardcopy map? (HINT: Use the Zoom tool to zoom in and read the metadata in the southwest corner of the map) _______

Now, let's compare the two DRG image files.

6. Zoom in to the southwest corner of the map so that you can see the map features and corner geographics. Now, display the o44106b2_datum2.tif file by checking the box in the Table of Contents. *If asked to Build Pyramid Layers, click **OK.***

Notice that the file displayed on top covers up the file underneath. That is because the digital 'paper' is not transparent. Let's change the transparency on the top file.

7. Double-click on the filename that is listed first in the Table of Contents. The Image Legend Editor dialog box opens.
   a. Click once on the **Colormap** button. The Image Colormap dialog opens.

DATUM EXERCISE – (cont.)

b. Now, double-click on the white symbol box representing color number 1. The Color Palette dialog box opens. Notice that the white box is currently selected, but we want white to be transparent.
c. Click on color transparency box which is the first box with an 'X' in it. Click the **Apply** button on the Image Colormap dialog. Close all the dialog boxes.

Your top image should be transparent and you will see the DRG that displays underneath.

Are the two files aligned?________________________. If not, why? ___________

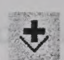
Can you tell which datum is which?_____________________________________

7. Close your ArcView session, but do not save your changes.

Viewing Datums in ArcMAP

1. To open ArcMAP, double-click on the desktop icon.

2. When the ArcMAP dialog box opens, click **OK** to open a new empty map.

3. Click on the **Add Data**  button on the Tool Bar.

4. In the Add Data dialog, from the **Look in:** dropdown menu, navigate to your data directory. Select two files by holding down the **SHIFT** key and selecting the 044106b2_datum1.tif and o44106b2_datum2.tif. Click **Add**. They automatically are added and displayed as layers in the Table of Contents.

5. Click on the **Zoom Tool**  and zoom into the southwest corner of the map. Check and uncheck the box next to the filename on the first file so that you can compare the two files in the display. Do they line up?_______________________ Why?___________________

Let's see what the source information says about the files.

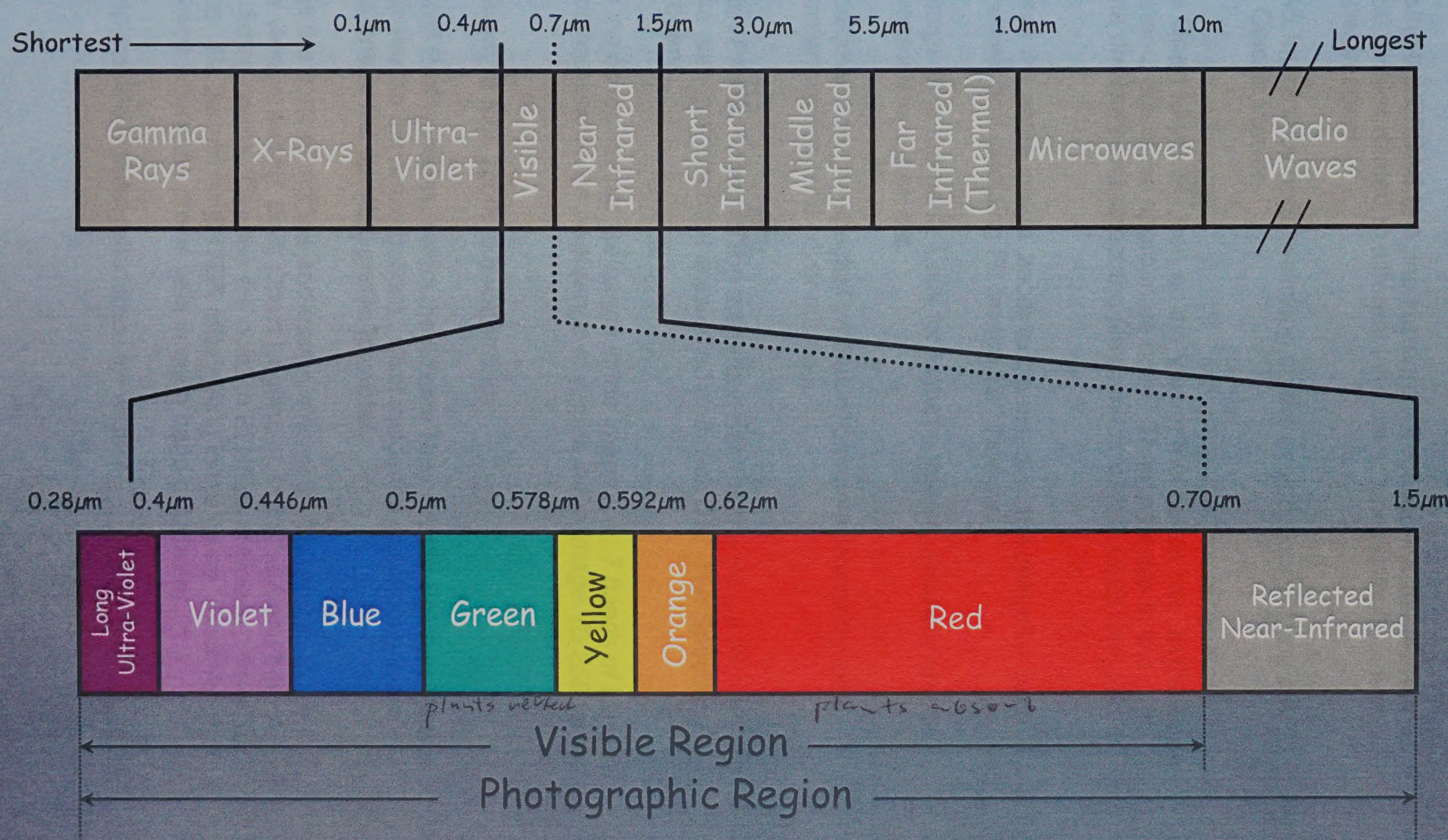
6. In the Table of Contents, click on the file name at the top of the list and right click. Select **Properties**. Click on the **Source** tab. In the Data Source box, scroll down until you find the datum that the file lists as its source. What is the datum?_____________________.

Now, check the **Source** for the other file in the Table of Contents. What is the datum?_____________________.

Why do they both display together in the view?________________________________

Close the ArcMAP session. Do not save.

The Electromagnetic Spectrum



SPECTRAL PROFILE EXERCISE

Objective: Using the ERDAS Imagine Histogram Tool you will identify and analyze spectral profiles related to different land cover types using Landsat Thematic Mapper imagery.

1. Start ERDAS Imagine by double-clicking on the desktop icon. If you are asked, open a Classic Viewer.

2. Click on the **Open Layer** icon on the Viewer tool button bar. In the **Look in:** dropdown menu, select the appropriate drive. Then, navigate to the appropriate data directory and select the file named tm3432_06251994.img. Click **OK**.

3. In order to see the entire image, zoom to the extent of the image by right-clicking in the viewer and selecting **Fit Image To Window.**

4. Study the image for a moment. Look for features that are distinctly unique. For example, vegetation, water, etc.

Next, you will discover how the spectral profiles of unique features can help distinguish between various land cover material.

5. Click on **Start Profile Tools** on the button bar. In the Select Profile Tool dialog box make sure that **Spectral** is selected and click **OK**. The Spectral Profile Viewer opens.

Notice that the x-axis represents the bands in the image (i.e., 7 bands of Landsat TM). The y-axis represents the pixel range of values in the image. (0-255 for 8-bit data).

6. Using the **Zoom In** tool, zoom to a water body.

7. In the Spectral Profile viewer, select the **Create New Profile Point in Viewer** tool (a crosshair next to the arrow button). Click inside the water body in the image viewer to create the spectral profile for water.

8. Let's change the color of the line and assign a name to the profile. In the Spectral Profile viewer, select, **Edit, Chart Legend**.....from the menu bar. A Legend Editor dialog opens. Change the color to BLUE, and type in 'Water' for the Profile name. Be sure to hit **ENTER** after typing in the name. Click **Apply** to see results. Notice where the profile falls in each band of Landsat.

Which band displays the highest reflectance for water?______________________

SPECTRAL PROFILE EXERCISE – (cont.)

Which band displays the lowest reflectance for water?____________________

9. Next, display the Legend in the Spectral Profile viewer. Select **Edit, Chart Options** from the menu. On the **General** tab, click in the box next to **Legend**, then, click **Apply.**

10. Create profiles for riparian vegetation, bare soil, upland grass, sand, snow, and rock.

To zoom back to the full extent of the image, right click in the view and select Fit Image To Window. Make sure to use the Zoom tool to get a good representative sample. As you collect each profile, assign it an appropriate color and name in the Legend Editor. Compare the results in the viewer.

*Note: To delete plots you don't want, select **Edit, Delete Plots**. Click to place an 'X' in the **Delete Plot** column to select the plots you wish to delete. Click **OK** to apply changes.*

Study the profiles. Notice how some landcover types have higher reflectance, while others have lower reflectance in the same band.

Therefore, to differentiate between landcover types, you want to select bands that provide the most discrimination between features.

In this image, what bands would you use to discriminate between:

1. riparian vegetation and upland grass?____________________
2. bare soil and rock?____________________
3. snow and sand?____________________
4. soil differences?____________________

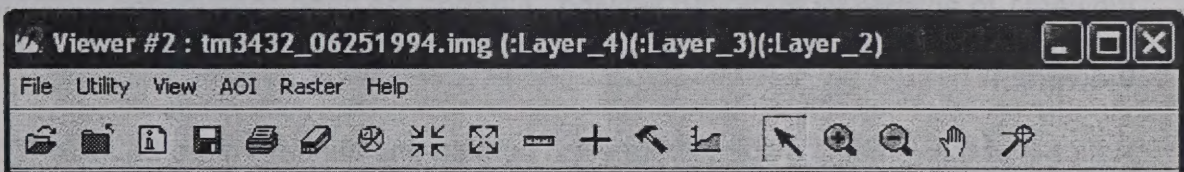
BAND COMPARISON EXERCISE

Objective: In this exercise you will compare dicover the spectral differences in the individual bands that comprise a Landsat Enhanced Thematic Mapper (ETM) image using ERDAS Imagine.

1. Open ERDAS Imagine by double-clicking on the desktop icon. If prompted, open a Classic Viewer.

2. On the viewer menu bar, click on the **Open Layer** icon on the button bar. Navigate to the appropriate directory. Make sure that **File of Type: IMAGINE Image (.img)** is selected. Open the file named tm3432_06251994.img. Right click in the viewer window and **Fit Image to Window** so that the entire image is displayed in the window. Study the water, snow, vegetation, and general landscape characteristics of the image.

Notice on the viewer title bar that next to the file name, the layers (bands) are listed in RGB order. Band 4 is displayed in the RED gun, Band 3 is in the GREEN gun, and Band 2 is in the BLUE gun. This portrays a false color-infrared composite image.



Now, let's see how the information that is displayed changes if you assign different bands of data to the color guns.

3. From the ERDAS main menu bar open another viewer. From the ERDAS Imagine main menu bar, select **Session, Tile Viewers** so that both viewers fit on the screen.

4. In the empty viewer open the same image file again. Fit the image to the window. You should now have two viewers with the same image displayed.

5. From the menu bar on Viewer#2, select **Raster, Band Combinations......** The **Set Layer Combinations** dialog box opens. Change the RGB band selection to 4,5,3. Click **Apply**. Study the discrete differences.

This band combination tends to bring out subtle differences in soil and moisture characteristics.

What color is snow on the 4,5,3 image?____________________________

What accounts for that difference?__________________________________

Study the variations in color in the riparian areas. What accounts for those differences?____

BAND COMPARISON EXERCISE – (cont.)

6. Now experiment with the following band combinations:
   a. 3,2,1
   b. 7,4,2
   c. 7,5,3

Try some of your own combinations.

7. From the ERDAS Imagine main menu, select **Session, Close All Viewers.**

Now you will begin to familiarize yourself with the image to be used for the **FINAL CLASS PROJECT**. This image is located in northeastern Wyoming.

First, let's look at each individual band that makes up the image.

1. Open a new viewer. From the menu bar, select **File, Open, Multi-layer Arrangement**. Select the file named tm3529_08272000_ms.img.

2. Viewer#1 contains the image in a 4,3,2 band combination. Drag the corner of Viewer#1 to enlarge for improved viewing. Change the band combination to one that enhances the image visually. Then, to re-tile all the viewers, select **Session, Tile Viewers**.

Notice that the remaining six viewers each contain one band from the Landsat ETM image. Compare the differences.

*You can resize each viewer manually, then select **Session, Tile Viewers** to return to the original display.*

Why does Layer_6 in Viewer#7 look coarser than the other images?__________
____

Why does Layer_6 in Viewer#7 look brighter than the other images?__________
____

What band enhances water bodies?______________

What 3 layers (bands) appear to enhance soil differences? _______________

3. Select **Session, Close All Viewers.** Open a new viewer and open the same file again.

4. Now, display the file using the 3 bands that you determined were best for displaying soil characteristics.

5. Close ERDAS Imagine. Do not save.

RESOLUTION EXERCISE

Part I:
Objective: In this exercise, we will use ERDAS Imagine to display and determine the different types of resolution inherent in any image.

1. Open Imagine by double-clicking on the Imagine desktop icon. Click OK to open a classic viewer.

2. In the Viewer1 window, click on the **Open Layer** icon on the button bar. In the **Select Layer To Add:** dialog, make sure the **File of Type:** IMAGINE Image (.img). Then, navigate to the appropriate data directory. Select the tm4036_08191993_subset.img file, and click **OK**. The Landsat TM image displays in the viewer. To display the entire image, right click in the viewer, and select **Fit Image To Window**.

3. Click on the **ImageInfo** button (third button from the left). The ImageInfo dialog box opens. Click on the **General tab**.

What is the projection? ____________________What is the datum?______________

What are the map (measurement) units? ________What is the Layer Type?______

What is the Data Type? ___________What is the pixel size (resolution)?________

What is the date of the image?____

How would you determine the spectral resolution?___________________________

Where is this image located in the US?__________________________________

4. Look at the information on the **Histogram** and **Pixel** tabs. Notice how that information changes when you select different layers.

Part II
Objective: In this part of the exercise you will compare the spatial resolution of different bands of a Landsat 7 Enhanced Thematic Mapper (ETM) image.

1. Start Imagine or open a new Viewer window.

2. In the Viewer1 window, click on the **Open Layer** icon on the button bar. In the **Select Layer To Add:** dialog, make sure the **File of Type:** IMAGINE Image (.img). Then, navigate to the appropriate data directory. Select the tm3529_08272000_pan.img file, and click **OK**. The Landsat ETM image displays in the viewer.

3. Click on the **ImageInfo** button.

RESOLUTION EXERCISE – (cont.)

What is the pixel resolution of this image?______________________________

How many bands or layers are in this image?____________________________

4. Close the ImageInfo dialog box.

Now, you will add the multispectral image on top of the panchromatic band in the view.

5. Click on the **Open Layer** button. Select the tm3529_08272000_ms.img. Select the **Raster Options** tab and uncheck the **Clear Display** option. Then, click **OK**. The multispectral image will display on top of the panchromatic display.

6. Open the **ImageInfo** for the multispectral image.

What is the pixel resolution of this image?______________________________

How many bands or layers are in this image?____________________________

7. Let's visually compare the two images. On the menu bar, click on **Utility, Swipe...** The Viewer Swipe dialog box will open. Use the number field or slider bar to control the percentage of the view pane that is displayed in the viewer.

Which image appears visually clearer?__________________Why?____________

8. Cancel the Swipe utility.

Now let's add a merged image that was produced by combining the spatial resolution of the panchromatic image and the spectral resolution of the multispectral image.

9. Click on the **Open Layer** button, and select the tm3529_08272000_432merge.img file. Be sure to click on the **Raster Options** tab and unselect the **Clear Display** option so that the image will draw on top of the others.

10. Select the **Utility, Swipe...** function again and compare the multispectral image with the merged image.

11. Select **View, Arrange Layers** from the menu bar. To compare the panchromatic image with the merged image, click and drag the tm3529_08272000_pan image above the tm3529_08272000_ms.img and click **Apply**. Again, use the **Swipe** utility to compare those two images.

12. Close ERDAS Imagine. Do not save your changes.

INFORMATION FOR DECISION MAKING SERIES

Satellite Images for Land Cover Monitoring

Navigating Through the Maze

Introduction

Policy makers, managers, scientists and the public can view the changing environment using satellite images. More than 60 Earth observing satellites are collecting images of the Earth's surface. Remote sensing satellite systems for land cover assessment are operated by a growing number of countries including India, the United States, Japan, France, Canada and Russia.

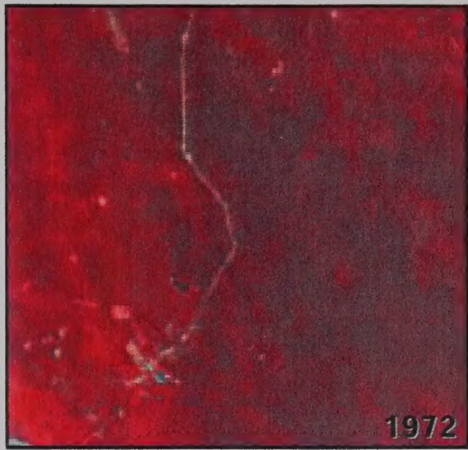
The focus of this publication is satellite systems for land cover monitoring. On the reverse is a table that compares a selection of these systems, whose data are globally available in a form suitable for land cover analysis. We hope the information presented will help you assess the utility of remotely sensed images to meet your needs.

What is Remote Sensing?

Remote sensing is the discipline of observing the Earth's surface without being directly in contact with it. It allows us to obtain information about our planet and humans activities from a distance, which can reveal interesting features that may not be possible or affordable from ground level. This gives a global perspective on changes and the interaction of our complex biosphere components.

The tools for remote sensing are sensors installed on planes or satellites. Airborne sensors are typically photographic cameras. Although an important source of environmental information, airborne image collections often are poorly documented and for small areas. In many countries the collection of airborne photographs is restricted.

Satellite sensors acquire images of the Earth and transmit the data to ground receiving stations located throughout the world. Once these raw images are processed and analyzed, they can document changing environmental conditions like pollution, global climate change, natural resource management, urban growth, sustainable development and much more.



Even though many satellite sensors monitor the earth, which sensor to use depends on the type of environmental information needed.

What Can Remote Sensing Do For You?

Remote sensing plays an integral role in environmental assessment. Remote sensing will never replace fieldwork but it offers great support in:

- Remote and difficult to access areas like dense forests, glaciated areas, swamps, high elevations, etc.
- Areas undergoing rapid changes.
- Countries with poor infrastructure and limited transportation.
- Areas of natural hazards: flooded areas, active volcanic regions, forest fire areas, etc.
- Constructing a broad overview or a detailed map of a large area.

Remote sensing techniques can increase the speed in which one can analyze a landscape and therefore help make quick and focused decisions.

Some applications include:

Agriculture and Forestry

- Discriminate vegetation, crop, and timber types.
- Measure crop and timber acreage.
- Estimate crop yields.
- Measure change in forest cover.
- Assess drought impact.
- Determine soil conditions.

Land Use Mapping and Economic Planning

- Map and monitor land cover changes.
- Monitor urban growth.
- Map of land-water boundaries.
- Site power plants and other industries.
- Site for transportation and transmission routes.

Geology and Geomorphology

- Recognize different rock types.
- Map major geologic units.
- Monitor surface mining and reclamation.
- Site solid waste storage.
- Monitor volcanic activity.

Water and Coastal Resources

- Determine surface water areas.
- Monitor environmental effects of humans activities.
- Map floods and flood plains
- Determine the extent of snow and ice.
- Measure glacial features.
- Map shoreline changes.
- Trace oil spills and pollutants.

Attention should also be paid to the fact that remote sensing allows multitemporal analysis. This means that an area of interest can be monitored over time so that changes can be detected. This allows us to analyze phenomena like vegetation growth during different seasons, the extent of annual floods, the retreat of glaciers or the spread of forest fires or oil spills.

Issues that Affect Selection of Images

Satellites and their sensors can differ in many ways. Most satellite sensors image the Earth with several bands where a band is sensitive to a specific range of wavelengths within the electromagnetic spectrum. The sensors discussed here are those sensitive to visible and infrared wavelengths. Beyond these wavelengths the interpretation of the data can become very specialized. However for some applications, wavelengths such as those used in radar sensors, are very important.

The defining characteristics of a sensor are the size of an image, the region of the Earth that can seen, the smallest feature that can be distinguished, the bands used, how often images are collected, and when was the sensor in operation. Important non-technical issues include acquisition costs and data sharing limitations. Licensing agreements vary over time, by product, by sensor and by organization.

How much area does an image cover?

The area covered by a single satellite image is defined by the path width and the distance along the path. The path width is limited by how far to each side the sensor can see. The path width can vary from as little as 8 kilometers to over 2000 kilometers. The distance along the path is more arbitrary. For high-to-medium resolution sensors the tendency is to create nominally square images. The image length for low resolution images may be an entire path.

Most Earth observing satellites orbit from pole to pole and are sun-synchronous, that is they always pass overhead at the same time of the day. Overlap between paths is least near the equator and most at upper latitudes. Areas close to the pole may not be covered at all. In contrast, some weather satellites are geostationary. They monitor only one hemisphere, but at all times of the day.

What is spatial resolution?

Spatial resolution of digital satellite sensors is the distance along the ground between samples. As the satellite moves across the Earth surface it records the brightness of the surface at regular intervals. The spatial resolution of a digital sensor is distinct from that of a photographic camera. The former is based on sampling rates, while the latter is based on the grain size in the film. If you zoom into a photograph, the image will degenerate into random noise. A satellite image will decompose into tiny black and white or colored squares or picture elements called pixels.

If a satellite image has a spatial resolution of 30 meters this means that one pixel in the image represents a square of 30 x 30 meters on the Earth's surface. In an image of this resolution one cannot see small buildings, but can definitely see a football field. Some sensors image the Earth with a very low resolution, more than 1 km, suitable for general land cover mapping of large features or monitoring vegetation vigor. Others, with a resolution of 1 meter, can resolve individual trees and are suitable for validation of coarser images.

What is spectral resolution?

As spatial resolution is a sampling of space, spectral resolution is a sampling of the electromagnetic spectrum. Conceptually many narrow bands would allow different types of land cover to be more easily distinguished. In reality, much of the information contained in narrow bands may be redundant. Sensor designers attempt to optimize the selection of the bands so that they can best distinguish between different types of land cover with the fewest number of bands. Typical bands are: blue, green, red, near infrared, mid infrared and thermal infrared.

The blue band has the best penetration of water, so is useful for coral reef and sea grass monitoring. Conversely, the blue band is very sensitive to moisture in the atmosphere, so in humid climates is very noisy. The green band is relatively high and the red band is relatively low for vegetation. The near-infrared bands are high for vigorously growing vegetation. Mid or short wave infrared bands are sensitive to moisture. Thermal infrared bands are sensitive to emitted thermal radiation, such as hot spots in a city or the temperature distribution of a lake.

What are repeat cycles and dates of operation?

The orbital paths of most operational satellites are fixed. The repeat cycle of a sensor is the number of days before an area can be seen again. The repeat cycle varies from every day to weeks. Some sensors have overlapping paths and some sensors are pointable which effectively reduces the period between repeat coverage.

The repeat cycle is critical for two reasons. One, some types of change or monitoring require frequent observations. Two, cloud cover may obscure the ground. Sensors with long repeat cycles, which tend to be high spatial resolution sensors, may only acquire a cloud free image once every several years in some climates.

How do these characteristics interact ?

Wide paths tend to be associated with low spatial resolution. High spatial resolution means large data volumes. Wide paths are linked to short repeat cycles.

Tradeoffs exist between spatial and spectral resolution. To achieve high spatial resolutions some sensors have a panchromatic band, which is essentially a very wide band.

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Tradeoffs exist between spatial and spectral resolution. To achieve high spatial resolutions some sensors have a panchromatic band, which is essentially a very wide band.

Satellite Remote Sensing for Environmental Assessment and Monitoring
Satellite sensors are available with resolutions from 1 m to 1 km. These resolutions are suitable for both large area and local applications.
In remote areas, satellite images may provide the only practical source of information.
For some applications, such as land cover analysis over large areas, no cost effective alternative exists.
Satellite images can be effectively analyzed either by image interpretation or by computer analysis.
Many satellite sensors collect images for the entire world.
Satellite image archives exist that document the Earth's surface back to the early 1960s.
Many of the satellite images can be acquired at no cost or at the cost of reproduction with no restrictions on image sharing.
In all cases, expert and local knowledge should be used to validate or guide the analysis of satellite images.

Disclaimers

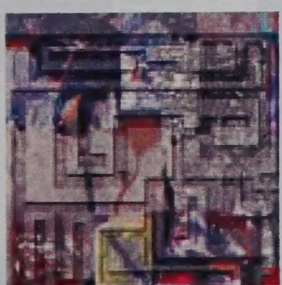
The views expressed in this text do not necessarily reflect those of the agencies cooperating in this project. Satellite sensor specifications may be approximated or summarized. The designations used and material presented above do not imply the expression of any opinion whatsoever on the part of the cooperating agencies concerning the legal status of any country, territory, city, or area or of its authorities, or of the delineation of its frontiers or boundaries.

Acknowledgements

This publication was prepared by Claudia Künzer and Gene Fosnight, UNEP/GRID–Sioux Falls. Our sincere appreciation to Bhaskar Ramachandran, Kim Giese, Rebecca Johnson, Saud Amer and Larry Tieszen, Raytheon Company, EROS Data Center for their valuable contributions to this publicaton.

Satellite Systems for Land Cover Monitoring

Navigating Through the Maze



For further information on remote sensing view:

http://www.na.unep.net/

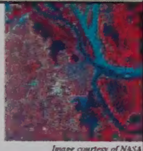
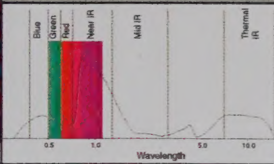
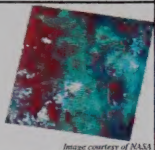
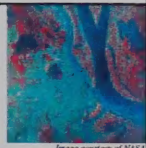
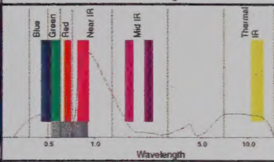
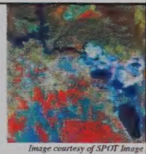
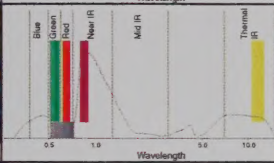
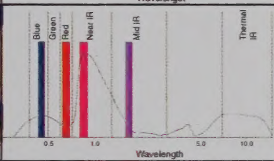
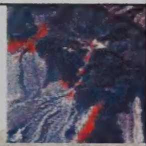
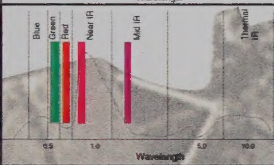
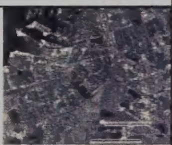
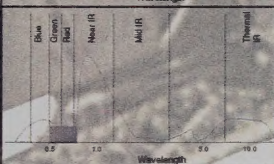
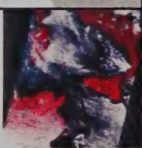
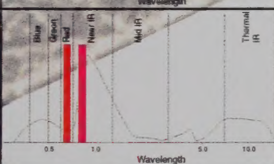
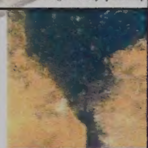
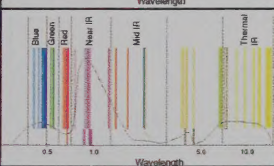
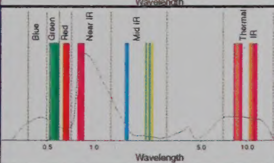
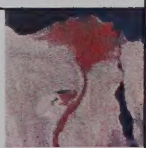
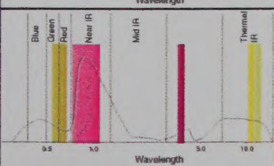
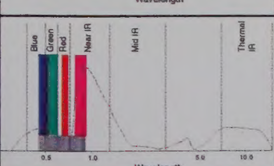
or contact:

Dr. Ashbindu Singh
Regional Coordinator, North America

UNEP Division of Early Warning and Assessment,
EROS Data Center, Sioux Falls, SD 57198

Phone: 605-594-6107 or 6117
Fax: 605-594-6119

Email: info@na.unep.net

Satellite Sensor	**Spatial Extent:** The total area covered by an image. The width of the image is the path width. The length of an image is not always constant, although a tendency exists for approximately square images. The nominal number of scenes needed to map Africa (30,264,000 km^2) and Costa Rica (50,000 km^2) are provided for each sensor. The actual number of scenes may be considerably higher depending on overlap and the shape of the country.	**Spatial Resolution or Pixel Size:** The spatial resolution of a sensor is a function of how frequently the sensor samples the ground. The pixel size is usually close to the sampling rate of the sensor. Objects on the ground need to be considerably larger than the spatial resolution to be detected. Example images are 375-by-375 pixels. The estimated number of land pixels for Africa and Costa Rica are provided for each sensor. Estimates are in millions of pixels.	**Spectral Resolution:** The sensors collect light in different parts of the spectrum. Grey line shows typical vegetation curve. Blue: penetrates shallow waters Green: high for green vegetation Red: low for green vegetation Near IR: high for vigorously growing vegetation Mid IR: sensitive to moisture variation Thermal IR: emitted thermal radiation	**Repeat Cycle and Dates in Operation:** Frequent coverage increases the chances of cloud-free images. Multiple images within a growing season allows knowledge of plant phenology to be used in land cover mapping. Images collected through many years allows the detection of land-use and land-cover change. In some cases more than one satellite is operational, decreasing the period between coverages.
Landsat — Multi-Spectral Scanner	185 km wide 170 km long Africa: 960 Costa Rica: 2 Phnom Penh, Cambodia  *Image courtesy of NASA*	80 m Africa: 5,000 Costa Rica:8 (with 30 m pxiels) Phnom Penh, Cambodia  *Image courtesy of NASA*		18 day repeat cycle for Landsats 1-3 16 day repeat cycle for Landsats 4 & 5 Operational since 1972 on Landsats 1-5.
Landsat — Thematic Mapper	185 km wide 170 km long Africa: 960 Costa Rica:2 Phnom Penh, Cambodia  *Image courtesy of NASA*	30 m bands 1-5,7 60 m thermal 15 m panchromatic Africa: 34,000 Costa Rica: 56 (with 20 m pixels) Phnom Penh, Cambodia  *Image courtesy of NASA*		16 day repeat cycle TM available since 1982 on Landsats 4 and 5. ETM+ available since 1999 on Landsat 7. The panchromatic band is only available on Landsat 7 ETM+
SPOT — Multi-spectral and Panchromatic	60 km wide 60 km long Africa: 8500 Costa Rica: 14 Sevilla, Spain  *Image courtesy of SPOT Image*	20 m multispectral 10 m panchromatic Africa: 76,000 Costa Rica: 125 Near Sevilla, Spain  *Image courtesy of SPOT Image*		26 day repeat cycle 5 day repeat viewing with pointable sensor Satellite operational since 1986.
SPOT — Vegetation	2200 km wide variable length Africa: 6 Costa Rica: 1 Nile River and Red Sea  *Image courtesy of SPOT Image*	1 km Africa: 31 Costa Rica: 0.05 Nile River and Delta  *Image courtesy of SPOT Image*		4 out of 5 day repeat cycle Satellite operational since 1986.
IRS — LISSIII	142 km wide 142 km long Africa: 1500 Costa Rica: 3 Iran  *Image courtesy of Space Imaging*	23.5 m 70 m mid IR Africa: 55,000 Costa Rica: 91 (with 23.5 m pixels) Iran  *Image courtesy of Space Imaging*		24 day repeat cycle Satellite operational since 1996.
IRS — Panchromatic	70 km wide 70 km long Africa: 6200 Costa Rica: 11 St. Petersburg, Russia  *Image courtesy of Space Imaging*	5.8 m Africa: 900,000 Costa Rica: 1500 St. Petersburg, Russia  *Image courtesy of Space Imaging*		24 day repeat cycle 5 day repeat viewing with pointable sensor Satellite operational since 1996.
IRS — WiFS	810 km wide 810 km long Africa: 50 Costa Rica: 1 Tunisia and Italy  *Image courtesy of Euromap*	188 m Africa: 860 Costa Rica: 1.5 Sicily  *Image courtesy of Euromap*		5 day repeat cycle Satellite operational since 1996.
Terra — MODIS	2330 km wide variable length Africa: 6 Costa Rica: 1 Nile River and Red Sea  *Image courtesy of NASDA*	250-1000 m Band dependent Africa: 500 Costa Rica: 0.8 (with 250 m pixels) Nile River and Delta  *Image courtesy of NASDA*		1 day repeat cycle Satellite operational since 2000.
Terra — ASTER	60 km wide 60 km long Africa: 8500 Costa Rica: 14 Phnom Penh, Cambodia  *Image courtesy of NASDA*	15 m vis and near IR. 30 m mid IR 90 m thermal IR Africa: 135,000 Costa Rica: 225 (with 15 m pixels). Phnom Penh, Cambodia  *Image courtesy of NASDA*		16 day repeat cycle 4 day repeat cycle with pointable sensor Satellite operational since 2000.
AVHRR	3000 km wide variable length Africa: 6 Costa Rica: 1 Nile River and Red Sea  *Image courtesy of NOAA*	1.1 km Africa: 26 Costa Rica: 0.042 Nile River and Red Sea  *Image courtesy of NOAA*		1 day repeat cycle Satellite operational since 1978.
Ikonos	11 km wide 11 km long Africa: 253,000 Costa Rica: 420 Sanaa, Yemen  *Image courtesy of Space Imaging*	4m multispectral 1m panchromatic Africa: 31,000,000 Costa Rica: 50,000 (with 1 m pixels) Sanaa, Yemen  *Image courtesy of Space Imaging*		5 day repeat cycle 1.5 day repeat viewing with pointable sensor Satellite operational since 1999.

Questions That Need to be Asked Before Using Satellite Images

Often simple answers do not exist for selecting and using satellite images in projects.

- Compromises may be required even in the most ideal scenario. In the simplest terms a satellite image must be available.
- No simple method exists for calculating cost of data acquisition. Many issues need be considered.
- Satellite images are pictures of the Earth. Cost and expertise is needed to extract information for the satellite images.
- Data providers fall into three broad and overlapping types: government agencies, quasi-public organizations and private companies. Services available and copyright issues need to be considered.

Criteria for sensor selection:

- Coverage: Are images available for your area?
- Spatial resolution: What size are the features you need to map?
- Spectral resolution: What types of features need to be distinguished?
- Dates of operation: During what years are images available?
- Repeat cycle: What types of variation through time are important: within or between years?

Criteria for image selection:

- How much cloud cover is acceptable?
- How critical is the time of year?
- How important is the year?
- If multiple images are needed, do they need to be in specific seasons of one year, the same season in multiple years, and so on?

Cost of data acquisition:

- Who you work for and where you live may affect cost of data.
- Redistribution policies may affect with whom you can share your data.
- Data may be available at little or no cost.
- If no-cost data are available, do they fit your needs: resolution, data of acquisition, and so on?

Cost of data analysis:

- Do you have staff to do the analysis or will the analysis be contracted?
- Satellite images can be either manually interpreted or they can be classified with a computer. Different types of expertise are needed and different types of costs are incurred.
- Is training needed? If so, what type of training?
- The cost of validating the quality of the analysis is often a forgotten and hidden cost. Without validation the value of the analysis is limited.

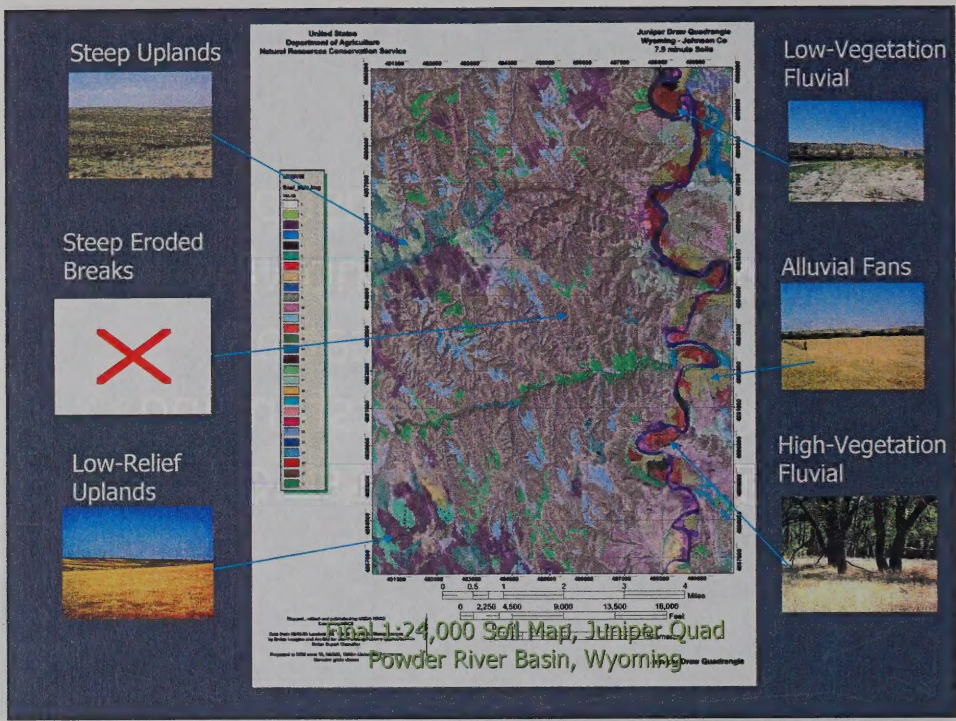
Other More Specialized Sensors Important for Land Cover Monitoring

- Radar sensors have all-weather capability for quantifying variation in surface roughness that is crucial for monitoring floods, fires, oil spills, wind speed and wind direction. Examples of radar sensors include Radarsat, ERS, JERS, SIR-C, Seawifs, and Seawinds
- Cameras were carried on many older satellites and continue to be used on many manned space missions. The older photographic images extend the environmental record back to 1962 and many are of high spatial resolution. Examples of space photography include Corona, Argon, Shuttle, Gemini and Apollo handheld, and TK-350, KVR-1000, MK-4, and KFA-1000.
- Sensors on geostationary satellites have the unique ability to provide continuous coverage of a region. These satellites are at much higher altitudes than are most Earth observing satellites and are designed for weather monitoring. A critical ability of sensors on these satellites is to monitor cloud cover and to provide rainfall estimates. Examples of these satellites include GMS, GOES-E, GOES-W, GOMS, Meteosat and Insat.
- Further information on new sensors as they are launched and on other specialized sensors such as DMSP, ATRS, TRMM, MISR, and QuikScat can be found at http://www.na.unep.net.

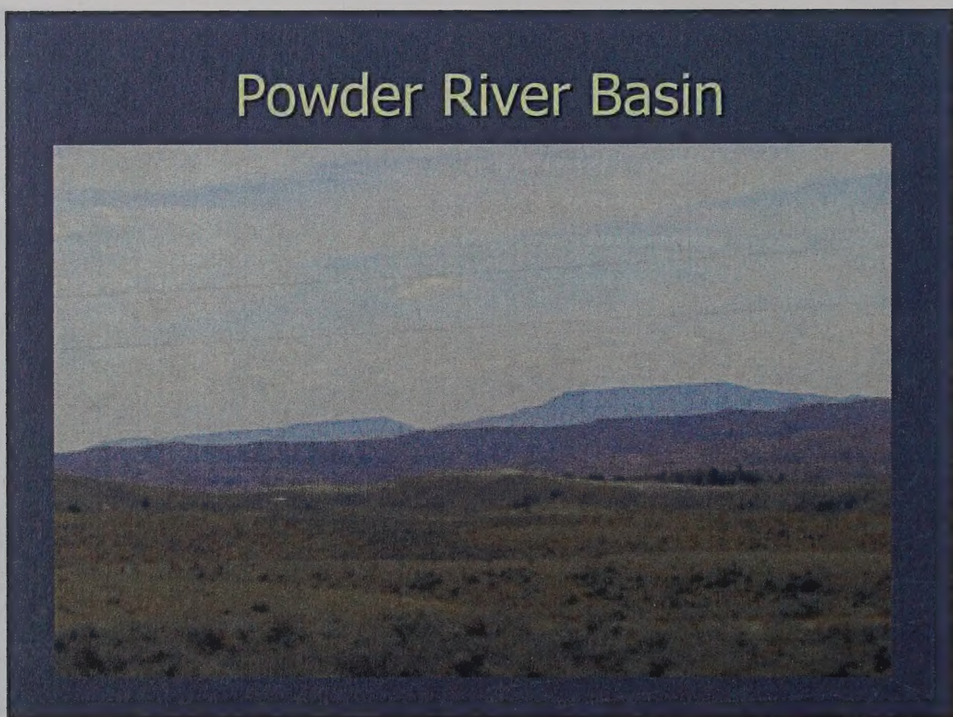
DEVELOPING
MAPS

ArcGIS Digitizing, Unsupervised, Supervised, and Knowledge-Based Classification: Pedogenic Understanding Raster-based Classification

- **Preliminary Stage**
  - Data Acquisition and Review
  - Pre-processing
  - Proxy Identification/Layer Stacking
  - Classifications
  - Field Review
- **Developmental Stage**
  - Knowledge Incorporation
  - Digital Model Development
  - Field Data Collection
  - Result Analysis
  - Refinement
- **Finalization Stage**
  - Model Finalization
  - Final Classification
  - Neighborhood Analysis
  - Vectorization
  - Polygon Editing
  - Final Field Verification



Steep Uplands
Steep Eroded Breaks
Low-Relief Uplands
United States Department of Agriculture Natural Resources Conservation Service
Juniper Draw Quadrangle Wyoming - Johnson Co 7.5 minute Scale
0 0.5 1 2 3 4 Miles
0 2,250 4,500 9,000 13,500 18,000 Feet
Final 1:24,000 Soil Map, Juniper Quad
Powder River Basin, Wyoming
Low-Vegetation Fluvial
Alluvial Fans
High-Vegetation Fluvial



Powder River Basin

Study Area

- Six 7.5-minute quads in Johnson County, north-central Wyoming
- Powder River Basin east of the Big Horn Mountains
- Joint interest area
  - Bureau of Land Management (BLM)
  - Natural Resources Conservation Service (NRCS)

Clmate

- MAT = 6.6° C: Mesic bordering on Frigid
- MAP = 28.9 cm: Soil moisture regime: Aridic bordering on Ustic

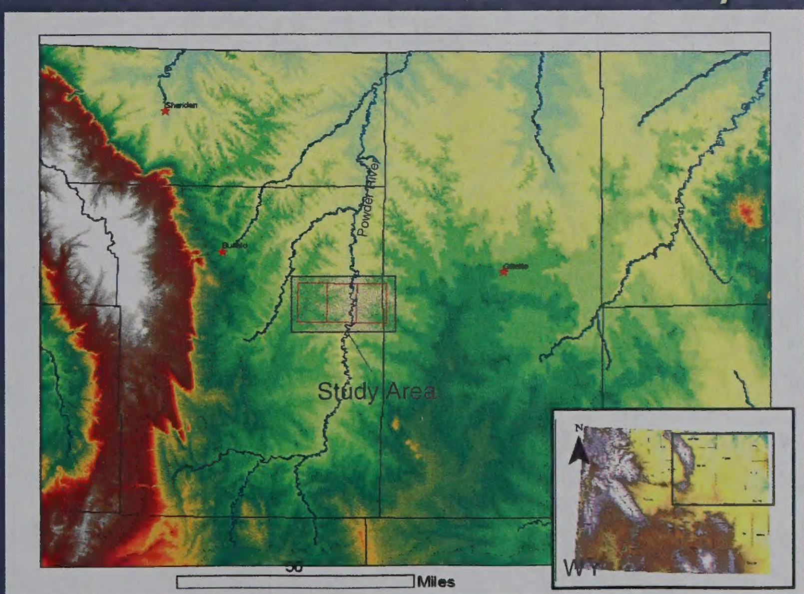
Parent Materials: Derived from Wasatch Formation

- Braided streams and alluvial fans make up deposits running west to east
- Meandering and mature streams ran north to south
- Sandstone, mudstone, siltstone and local conglomerates
- 20 mya to present, no rock record

"Modern fluvial analogues (to the ancient Powder River Basin) indicate similarities with... the Mahakam River in the Kutai Basin (Borneo)."-R.M. Flores, U.S. Geological Survey

Powder River Drainage

Powder River Basin Today



Relief: Geomorphology

- Badlands
  - High rates of erosion
  - Low vegetation density
  - Continual disturbance
  - High rates of pedogenic rejuvenation

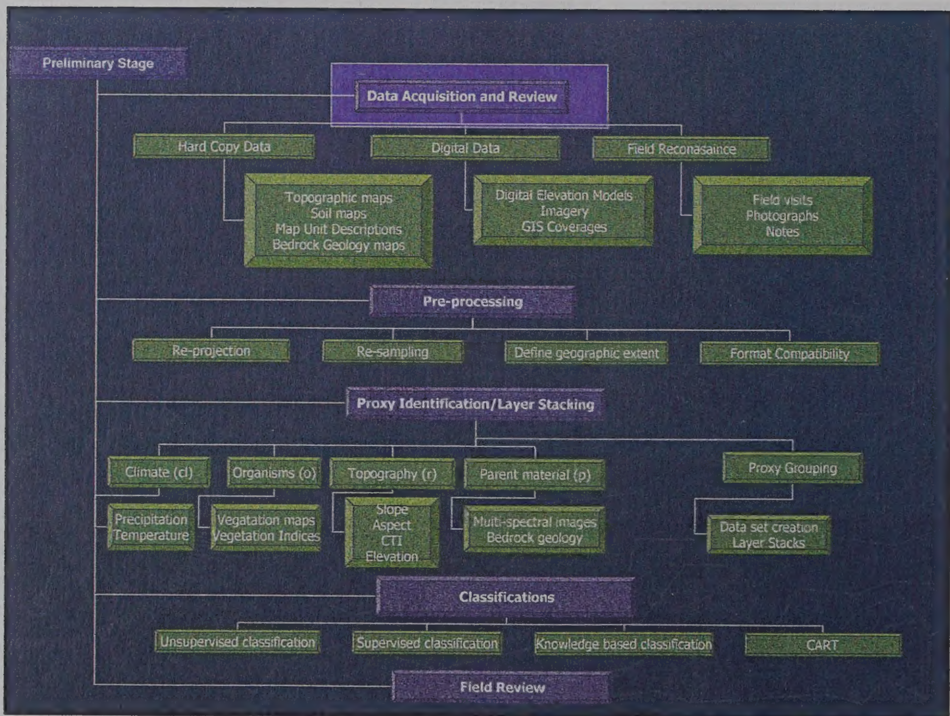
- Uplands
  - Higher grass density in sandy areas
  - Higher sagebrush density in loamy soils
- Deep ravines

- Rocky slopes
  - Juniper stands

- Alluvial fans
- Riparian areas
- Meander belts
- Floodplains

Organisms: Vegetation

- *Artemisia tridentata* (Sagebrush)
- Prairie grasses (i.e. *Agropyron smithii*)
- *Juniperous scopulorum* (Rocky Mountain Juniper)
- *Populus spp.* (Cottonwood)



Acquire Hard Copy Data

- Hard copy data
  - Bedrock geology
  - Topographic maps
  - Soil maps
  - Map unit descriptions

Acquiring Digital Data and Using Digital Data in a Geographic Information System

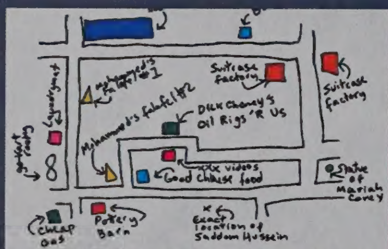
What is a GIS?

Geographic Information System (GIS)

- Marriage
  - Computer cartography (computer-aided map-making)
  - Spatial databases
- Data become spatially explicit
- Data can be viewed and manipulated
  - Visually
  - Statistically
  - Mathematically

Basic GIS Principles

- **Vector data**
  - Composed of points, lines, and polygons
- **Raster data**
  - Composed of individual pixels
  - Each pixel has its own identity
  - Raster layers can be mathematically combined or manipulated



Scott Ritter's personal map of Baghdad, mistakenly used by President Bush as evidence against Saddam Hussein

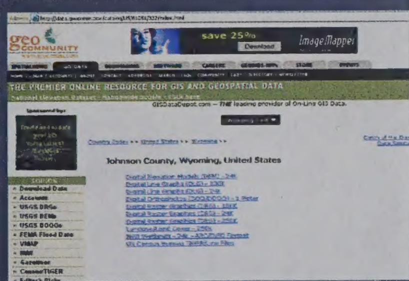
GIS Relief Data Layers

- DEM (Digital Elevation Model)
  - Raster (pixel, grid)
  - Elevation (meters)

5	5	6	6	5	4	3
5	4	5	6	5	4	3
5	5	6	7	6	5	4
6	6	7	8	7	6	5
4	4	5	6	5	4	3
3	3	4	5	5	4	2
2	2	2	3	2	2	1

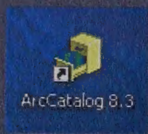
Acquire Digital Data

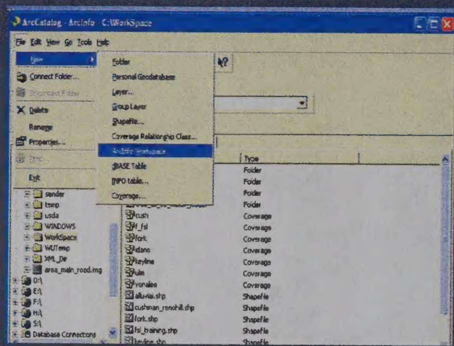
- Digital Data Sources
  - http://data.geocomm.com/
  - http://glovis.usgs.gov/
  - http://www.agrc.utah.gov/
  - Government Agency GIS websites



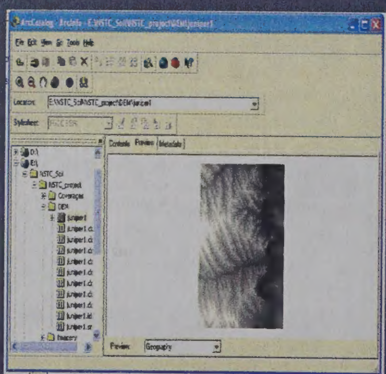
Reviewing Digital Data

- Open ArcCatalog
  - Locate and double click ArcCatalog Icon

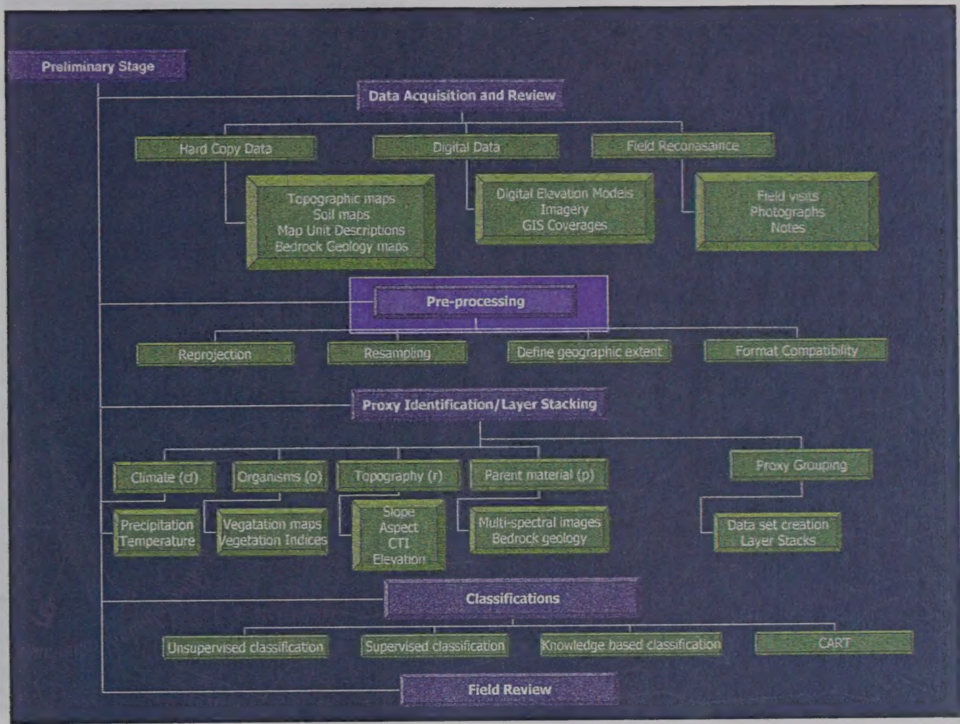




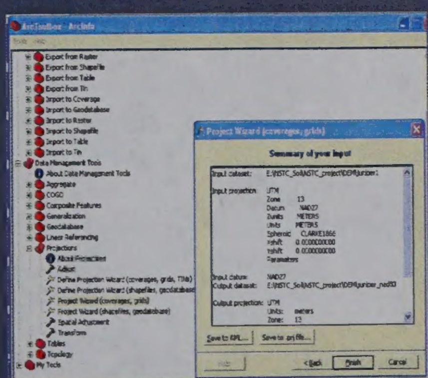
Review Data in ArcCatalog



- Look in "Exercise"
  - Click on Juniper_DEM27
  - Click *Preview*
    - Build pyramids
  - Right click on Juniper_DEM27
    - Click *Properties*
    - Projection?



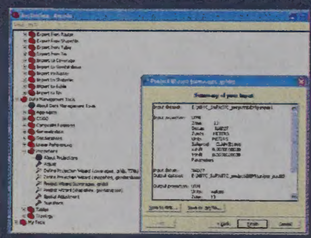
Pre-Processing DEMs



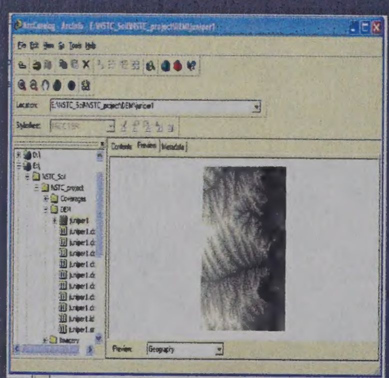
- Open ArcTools
  - Select "Data Management Tools"
  - Select "Projections"
  - Select the "Project Wizard" for grids and coverages

Project Wizard (Grids and Coverages)

- Project your data to a specified coordinate system
  - Identify the data you will change (the Juniper_DEM27)
  - Select the following for projection:
    - *UTM*
    - *Units* = meters
    - *Zone* = 13
    - No X or Y shift
    - *Datum* = NAD83
    - Store in your "Exercise" folder as Juniper_NAD83
    - Accept defaults
    - *Finish*



Review Processed Data in ArcCatalog



- Use "F5" to refresh the catalog
- Select Juniper_NAD83
  - Click preview
  - Build pyramids
- Right click Juniper_NAD83
  - Click properties
  - Projection?

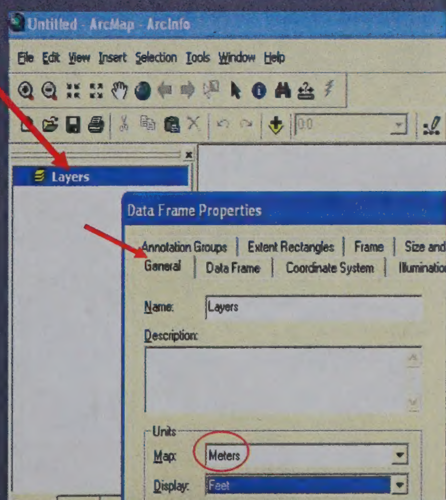
Always Check Projections

Using ArcGIS

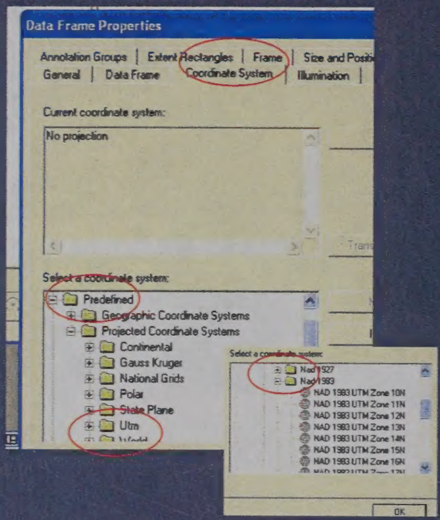
Double Click ArcMap icon on desktop

Defining Session Properties

- Double Click *Layers*
  - Click *General* tab
  - Map units = Meters
  - Display = Meters



Defining View Projection



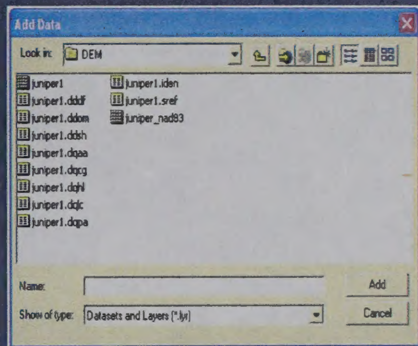
- Click on *Coordinate System* tab
  - Select "Predefined"
  - Select "Projected…"
  - Select "Utm"
  - Select "NAD83 Zone 13"

Once your projection is set for an ArcMap session projected data that you bring in will reproject on the fly.

Is that good or bad?

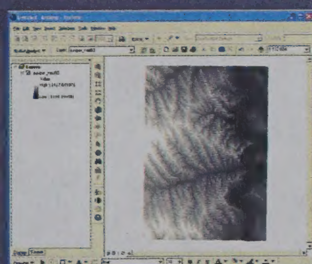
Adding Data

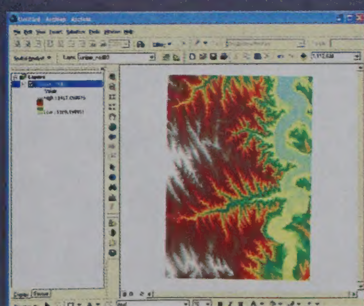
- With ArcMap open
  - Add Data using the button shown above
  - Locate "Exercise" folder
  - Add Juniper_NAD83 DEM

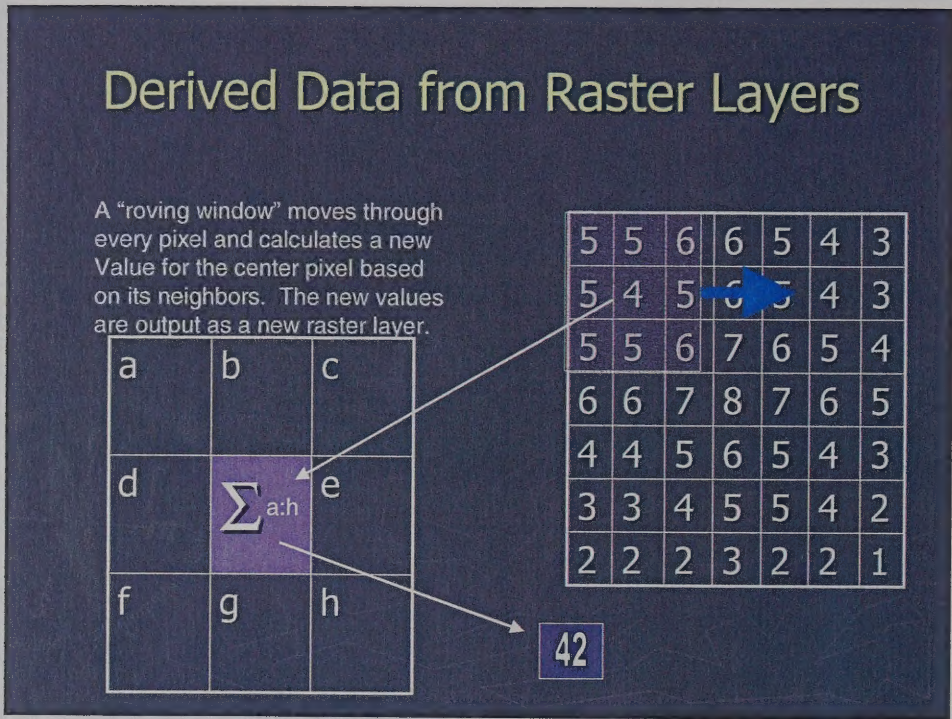


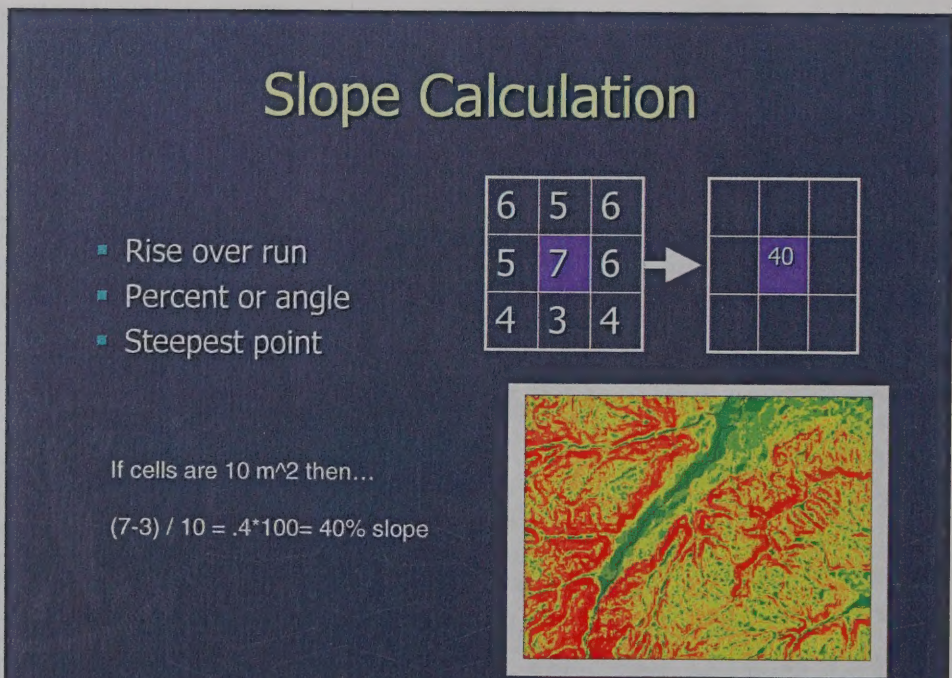
Changing Symbology

- Right click on Juniper_NAD83
- Click *Properties*
- Click *Symbology*
- Locate *Color Ramp*
- Change the ramp
- Click *OK*





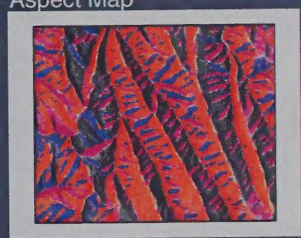

Derived Data from Raster Layers
A "roving window" moves through every pixel and calculates a new Value for the center pixel based on its neighbors. The new values are output as a new raster layer.
a
b
c
d
$\sum$ a:h
e
f
g
h
42
5 5 6 6 5 4 3
5 4 5 4 3
5 5 6 7 6 5 4
6 6 7 8 7 6 5
4 4 5 6 5 4 3
3 3 4 5 5 4 2
2 2 2 3 2 2 1


Slope Calculation
Rise over run
Percent or angle
Steepest point
If cells are 10 m^2 then…
(7-3) / 10 = .4*100= 40% slope
6 5 6
5 7 6
4 3 4
40
Slope map

Aspect Calculation

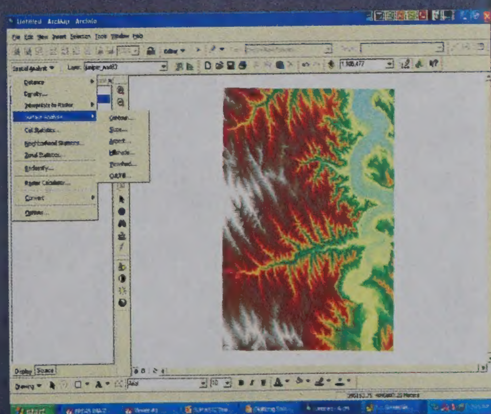
- Direction
  - Vector perpendicular to the plane of the slope
  - Values 0-360 (degrees)
  - Southern aspect is 180

Aspect Map



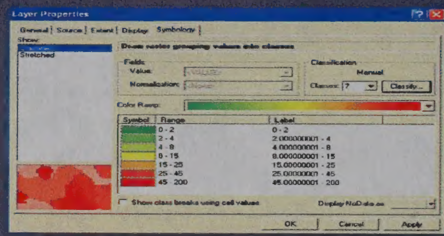
Deriving Topographic Data: Slope ArcGIS Spatial Analyst

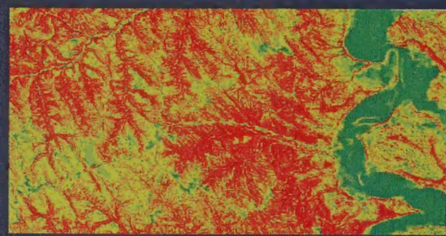
- Open *Spatial Analyst*
  - Select *Surface Analysis*
  - Select *Slope*
  - Input = Juniper_NAD83
  - Output = percent
  - Z factor = 1
  - Cell Size = 10m
  - Output Raster = J_slope



Displaying Slope Data

- Right click J_slope
- Go to *Properties*
- Show *Classified*
- Classes = 7
- Select *Classify*
- Enter slopes at
  - 2
  - 4
  - 8
  - 15
  - 25
  - 45
  - 200
- *OK*





Deriving Topographic Data: Aspect

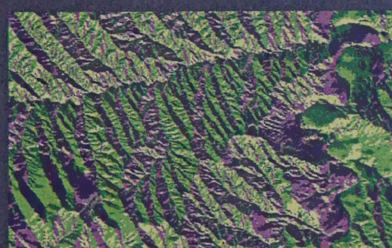
- Open *Spatial Analyst*
  - Select *Surface Analysis*
  - Select *Aspect*
  - Input = Juniper_NAD83
  Cell Size = 10m
  - Output Raster = J_aspect
- Add J_aspect to your project

Deriving Topographic Data: Hillshade

- Open *Spatial Analyst*
  - Select *Surface Analysis*
  - Select *Hillshade*
  - Input = Juniper_NAD83
  - Azimuth = 180
  - Altitude = 25
  - Z factor = 1
  - Cell Size = 10m
  - Output Raster = J_hill
- Add J_hill to your project

Topographic Data Discussion

- Other layers
  - Compound Topographic Index (CTI)
  - Flow Direction
  - Flow Accumulation
  - Plan and profile curvature
  - Roughness
  - etc..
- Aspect
  - What are possible problems?
  - What is the solution



Imagery (Remotely Sensed Data):

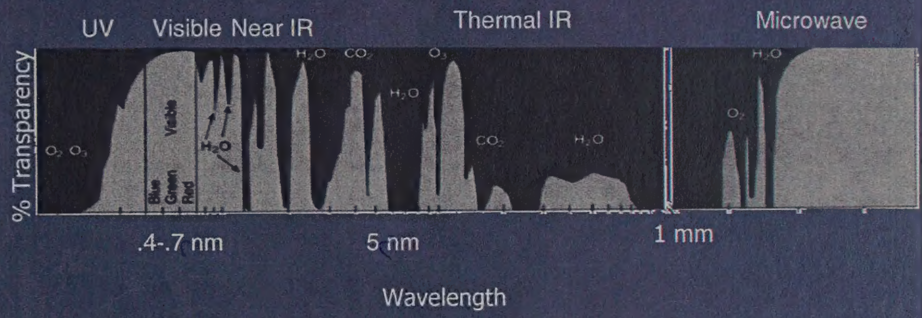
- Aerial Spectral Data
  - Photography
  - Hyperspectral
    - AVIRIS, etc.
- Satellite-Derived Spectral Data
  - Landsat, ASTER, IKONOS, etc.

Higher resolution (spatial or spectral) = Higher cost

Basic RS Principles

- All objects
  - Emit radiation based on their temperature
  - Reflect radiation based on physical properties
  - Transmit based on their physical properties
  - Absorb radiation on their physical properties
- Unique electromagnetic signature
  - Grass looks different than asphalt

Basic RS Principles: Transmitted Radiation



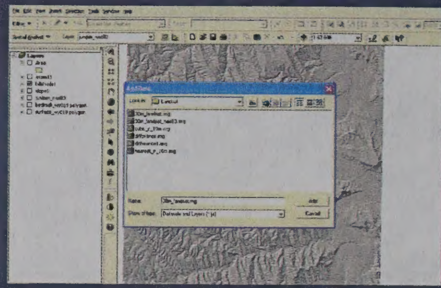
Landsat 7 RS Data

Landsat 7 true color image

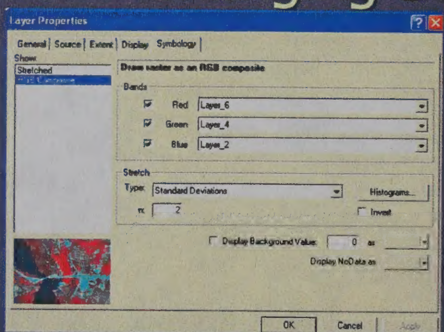
Band	G-Resolution	Spectral Range (microns)	
1	30	.45 to .515	-Blue
2	30	.525 to .605	-Green
3	30	.63 to .690	-Red
4	30	.75 to .90	-NIR
5	30	1.55 to 1.75	-MIR
6	90	10.40 to 12.5	-TIR
7	30	2.09 to 2.35	-MIR
Pan	15	.52 to .90	-Visible + NIR

View RS Data in ArcGIS

- Add Data
  - Select "Landsat" folder
  - Select 30m_landsat.img

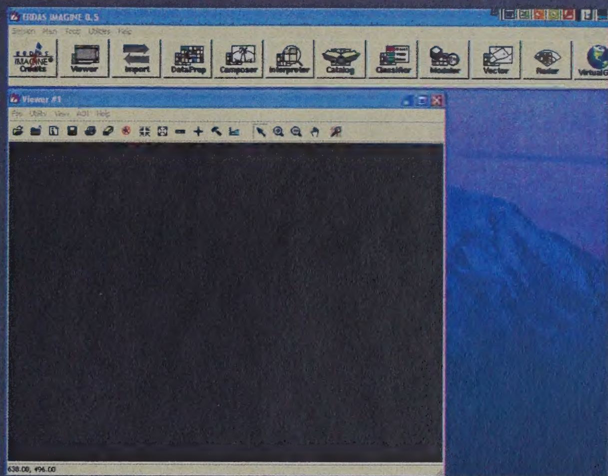


Changing Display (Gun)



- Right click 30m_landsat.img
  - Select *Properties*
  - Select *Symbology*
    - RGB Composite
    - *Red* = Layer_6
    - *Green* = Layer_4
    - *Blue* = Layer_2
- Why change bands?

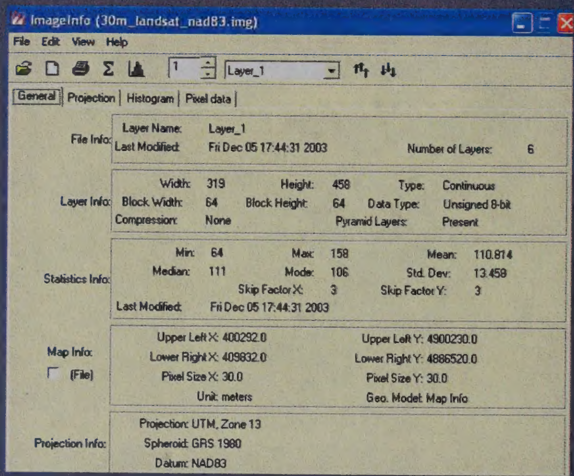
Open Erdas Imagine



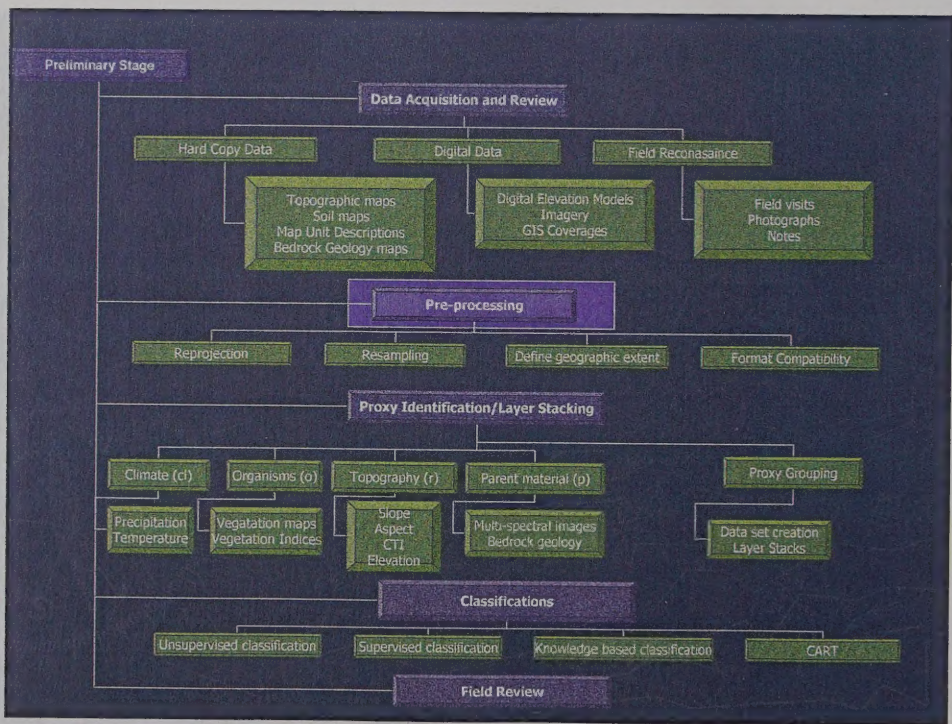
Viewing Raster Data in Erdas Imagine

- *Geospatial Light Table* (GLT, a new viewer)
- Select *File* pulldown
  - Select *Open*
    - *Raster Layer*
    - Click 30m_landsat.img
  - Far right
    - *Red* = 4
    - *Green* = 3
    - *Blue* = 2

Image Data



ImageInfo (30m_landsat_nad83.img)
File Edit View Help
Layer_1
General
Projection
Histogram
Pixel data
File Info:
Layer Name: Layer_1
Last Modified: Fri Dec 05 17:44:31 2003
Number of Layers: 6
Layer Info:
Width: 319
Height: 458
Type: Continuous
Block Width: 64
Block Height: 64
Data Type: Unsigned 8-bit
Compression: None
Pyramid Layers: Present
Statistics Info:
Min: 64
Max: 158
Mean: 110.814
Median: 111
Mode: 106
Std. Dev: 13.458
Skip Factor X: 3
Skip Factor Y: 3
Last Modified: Fri Dec 05 17:44:31 2003
Map Info:
(File)
Upper Left X: 400292.0
Upper Left Y: 4900230.0
Lower Right X: 409832.0
Lower Right Y: 4886520.0
Pixel Size X: 30.0
Pixel Size Y: 30.0
Unit: meters
Geo. Model: Map Info
Projection Info:
Projection: UTM, Zone 13
Spheroid: GRS 1980
Datum: NAD83



Preliminary Stage
Data Acquisition and Review
Hard Copy Data
Digital Data
Field Reconasaince
Topographic maps
Soil maps
Map Unit Descriptions
Bedrock Geology maps
Digital Elevation Models
Imagery
GIS Coverages
Field visits
Photographs
Notes
Pre-processing
Reprojection
Resampling
Define geographic extent
Format Compatibility
Proxy Identification/Layer Stacking
Climate (cl)
Organisms (o)
Topography (r)
Parent material (p)
Proxy Grouping
Precipitation
Temperature
Vegatation maps
Vegetation Indices
Slope
Aspect
CTI
Elevation
Multi-spectral images
Bedrock geology
Data set creation
Layer Stacks
Classifications
Unsupervised classification
Supervised classification
Knowledge based classification
CART
Field Review

Pre-Processing Imagery: Atmospheric Correction

- Correcting for the effects of selectively scattered light in multi-spectral images.
  - Shorter wavelengths = greater scattering

Chavez, P.S. Jr., 1996, Image based atmospheric corrections-revisited and revised. *Photogrametric Engineering and Remote Sensing* 62(9): 1025-1036

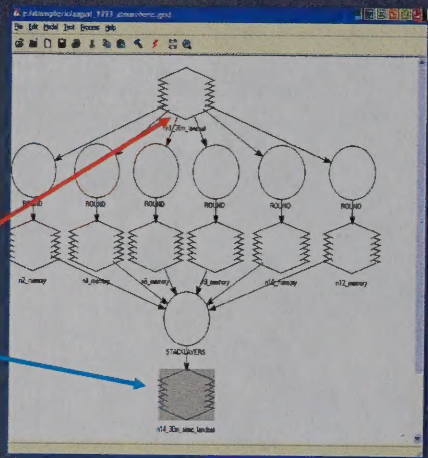
COST Atmospheric Correction (Cosine τ)

$$\rho_{BandN} = \frac{\pi((DN_{bandN} * Gain_N + Bias_N) - (DO * Gain_N + Bias_N)) * D^2}{E_{bandN} * (COS((90-\theta) * \pi/180)) * \tau}$$

ρ = Reflectence
π = 3.14.........
DN = Digital number of the specified band (changes with each pixel)
DO = Digital number of a "dark object" for the specified band (40)
D = Earth Sun Distance (date specific) = 1.0128 in Astronomical Units
E = Solar Irradiance for specific band = 1957
τ = Atmospheric transmittance = $(COS((90-\theta) * \pi/180))$
θ = Sun Elevation (angle) (50)
Gain = band specific (.602431)
Bias = band specific (-1.52)

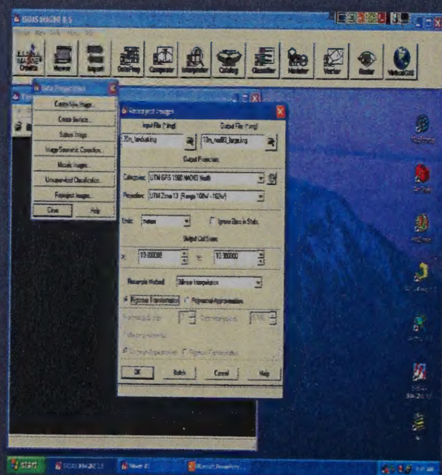
COST Atmospheric Correction

- Open *Modeler*
  - *Model Maker*
    - *File*
    - *Open*
    - August_1993_atmospheric.gmd
  - Input = 30m_landsat
  - Output = 30m_atmc_landsat
- *Run* (lightning bolt)
  - Open in your GLT viewer



Pre-processing: Reproject/Resample

- Select *DataPrep*
  - *Reproject Images*
  - *Input* = 30m_atmc_landsat
  - *Output* = 10m_atmc_nad83
  - *Category* = UTM GRS 1980 NAD83 north
  - *Projection* = UTM zone 13
  - *Inputs* = meters
  - X, Y = 10.00
  - *Reprojection Method* = Cubic Convolution
  - *Rigorous Transformation*



Resampling Methods

- Nearest Neighbor
  - Cuts 1-30m into 9-10m pixels having same value
  - Least change
- Bilinear Interpolation
  - Cuts 1-30m into 9-10m pixels
    - New values interpolated from 4 most proximate
  - Moderate change
- Cubic Convolution
  - 1-30m Pixel into 9-10m pixels
    - New values interpolated from a curve created by nearest 16 pixels
  - Most change

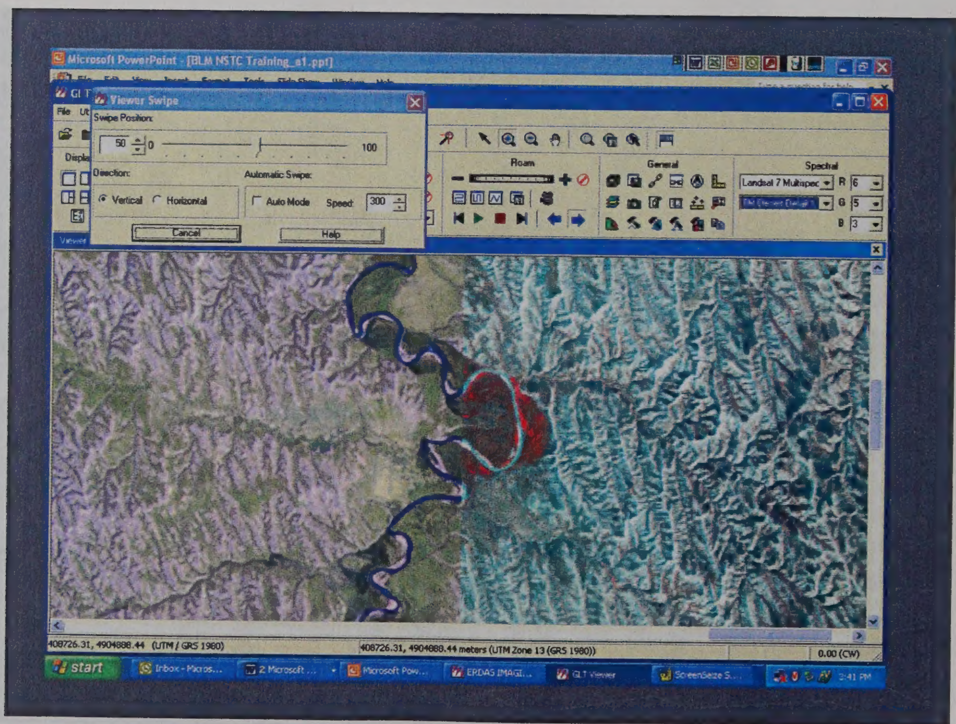
Pre-Processing: Cubic Convolution

- Change in a sample of a 496,829,690 pixel area
- Values are in Digital Number (0-255)

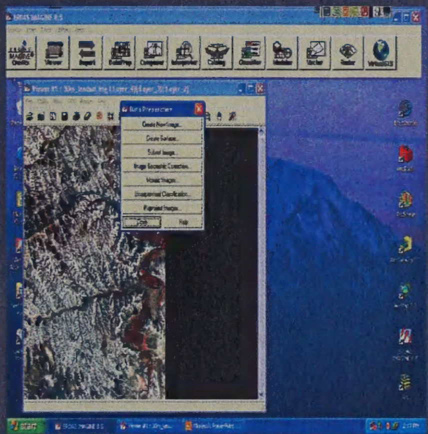
Layer	Min	Max	Std	Mean change
Band1	0	39	.231	.65
Band2	0	58	.363	.972
Band3	0	53	.142	1.58
Band4	0	65	.698	1.798
Band5	0	62	.868	2.243
Band6	0	52	.865	2.148

Comparison 30m vs 10m: Cubic Convolution

- In viewer
  - Open raster layer
    - 10m_atmc_nad83
- Before hitting *OK*
  - Raster options
  - De-select *Clear Display* tab
  - *OK*
- Now under *Utility* select
  - *Swipe*



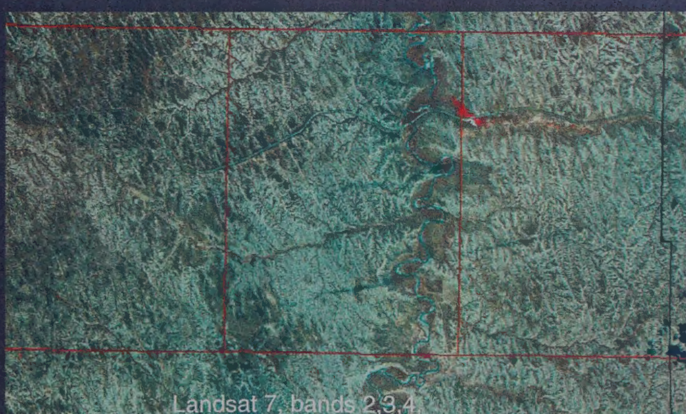
Pre-Processing: Defining Geographic Extent



- Select *DataPrep*
  - *Subset Image*
  - *Input* = 10m_atmc_nad83
  - *Output* = 10m_j_lsat_nad83
  - *AOI* = Juniper_quad

Landsat 7 RS Data: Vegetation

- Properties of vegetation
  - High adsorption of red light
  - High reflectance of near infrared (NIR)

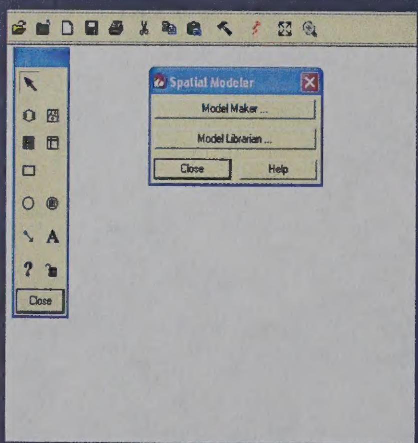


Landsat 7 RS Data: Vegetation

- Vegetation indices
  - Red and infrared levels are ratioed
  - Normalized Difference Vegetation Index (NDVI)
  - Values 1.0 to -1.0
  - Higher value indicates higher vegetation density

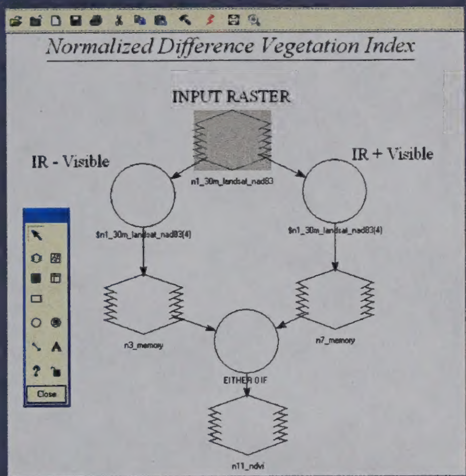
$$NDVI = (NIR-R)/(NIR+R)$$

Building a Model In Erdas Imagine



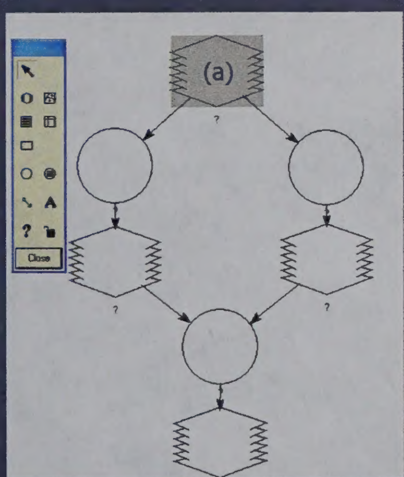
- Select *Modeler*
  - Click "*Model Maker*"
  - Click on the *hammer* tool symbol

NDVI

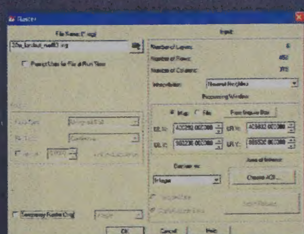


- Using the toolbar add
  - One image box
    - Point two arrows to
  - Two function circles
    - Point arrows to
  - Two image boxes
    - Arrows converge at
  - One function circle
    - Single arrow to
  - One image box

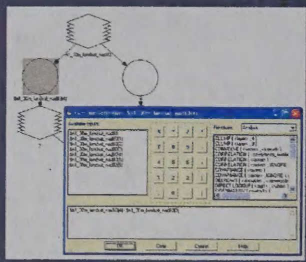
Adding Elements

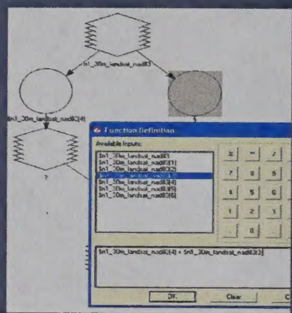


- First image box (a)
  - 10m_j_lsat_nad83



Input Formulas

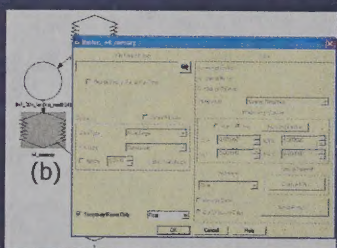


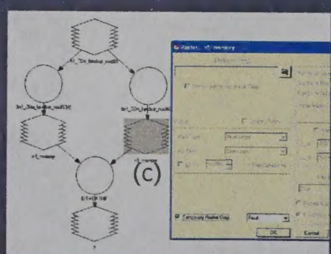


- First function circle =
  - Band 4 (NIR) – Band 3 (R)

  (double click the layer to add it to the box)
- Second function circle =
  - Band 4 + Band 3

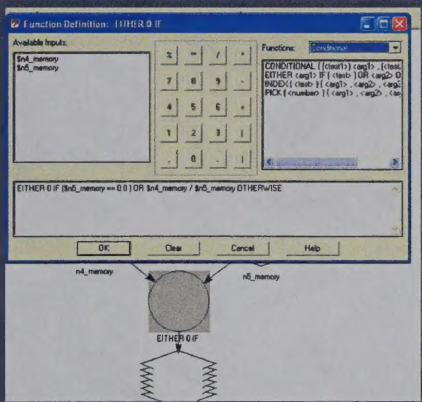
Create Output Locations





- Second image box (b)
  - *Make temporary*
- Third image box (c)
  - *Make temporary*

Final Conditional Statement

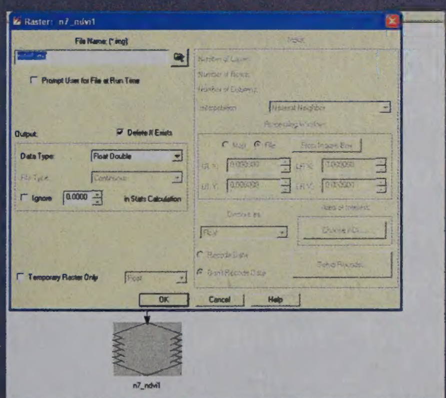


- Final function =
  - *Conditional*
  - *Either*
- EITHER 0 if box (c) == 0 OR box (b) / box (c) OTHERWISE

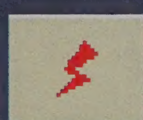
Boxes will be called $n(somenumber)memory

- main point: the denominator box can't equal zero

Final Output

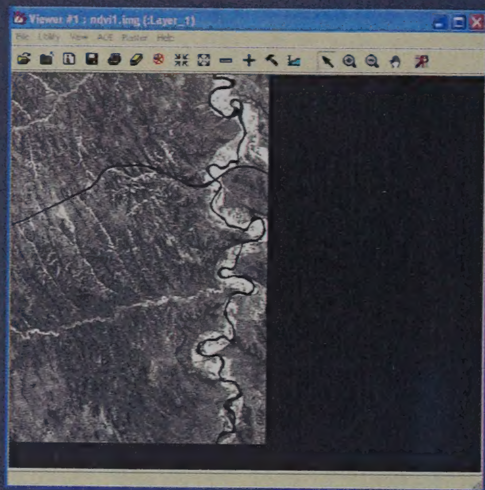


- Final image box
  - *Name* j_ndvi
  - *Delete if exists*
  - *Data type* = float double
  - *OK*
- *Run* by clicking the lightning bolt



View NDVI

- Open j_ndvi in Imagine
  - What are the values?



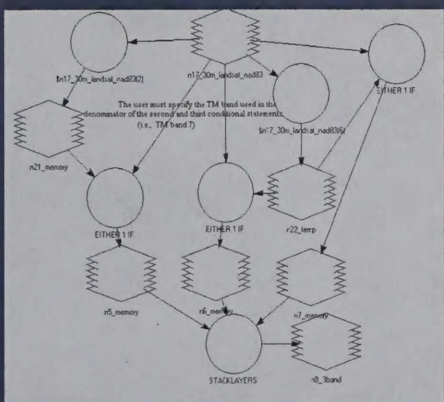
Data Layers - Organisms

- GAP data
- Soil Adjusted Vegetation Index (SAVI)
  - SAVI=[(NIR-R)/(NIR+R+.5)]*1.5
- Perpendicular Vegetation Index (PVI)
- Fractional Vegetation Index
  - Uses values derived from indices
  - [(NDVI – min NDVI)/(max NDVI – min NDVI)]*100
    - Vegetation is expressed as a percent

Data Layers – Parent Material

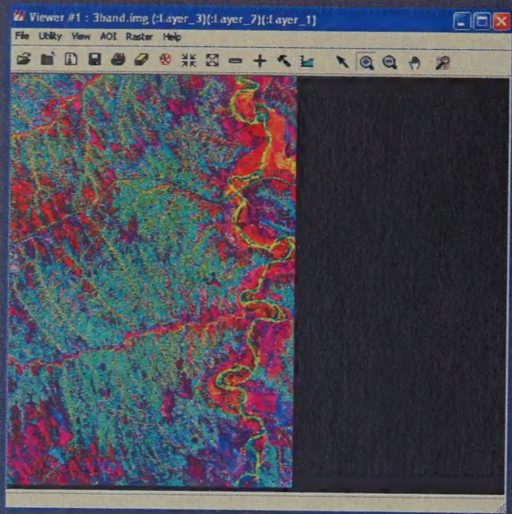
- Soil Enhancement Composite (3 Band Mineralogy)
  - Uses Landsat TM data
    - Band 3/ Band 2 (Blue)
      - Carbonate radical
    - Band 3 / Band 7 (Green)
      - Ferrous iron
    - Band 5 / Band 7 (Red)
      - Hydroxyl radical

Soil Enhancement Model



- Open *Model Maker*
- Navigate to "Exercise" directory
- Select soil_enhancement.gmd
- *Input* = 10m_lsat_nad83
- Check expressions
- *Output* = soil_enhancement
- *Run*

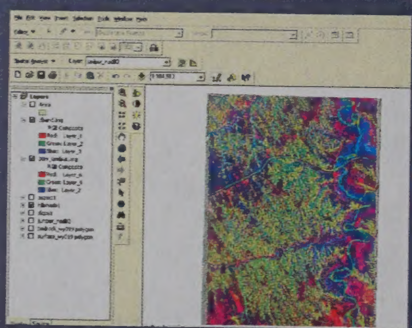
Parent Material?



- What does this image show?
- Why?
- What are the setbacks?

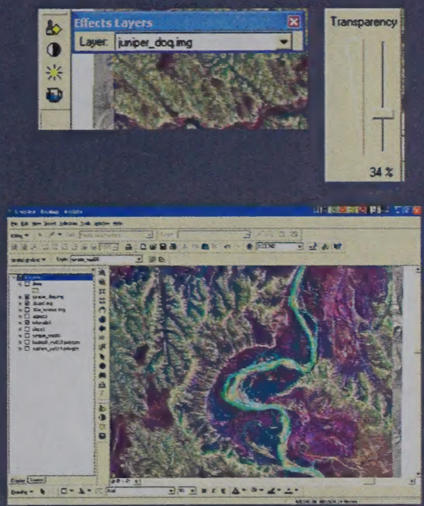
Field work needed!

Viewing Multiple Layers: Transparency



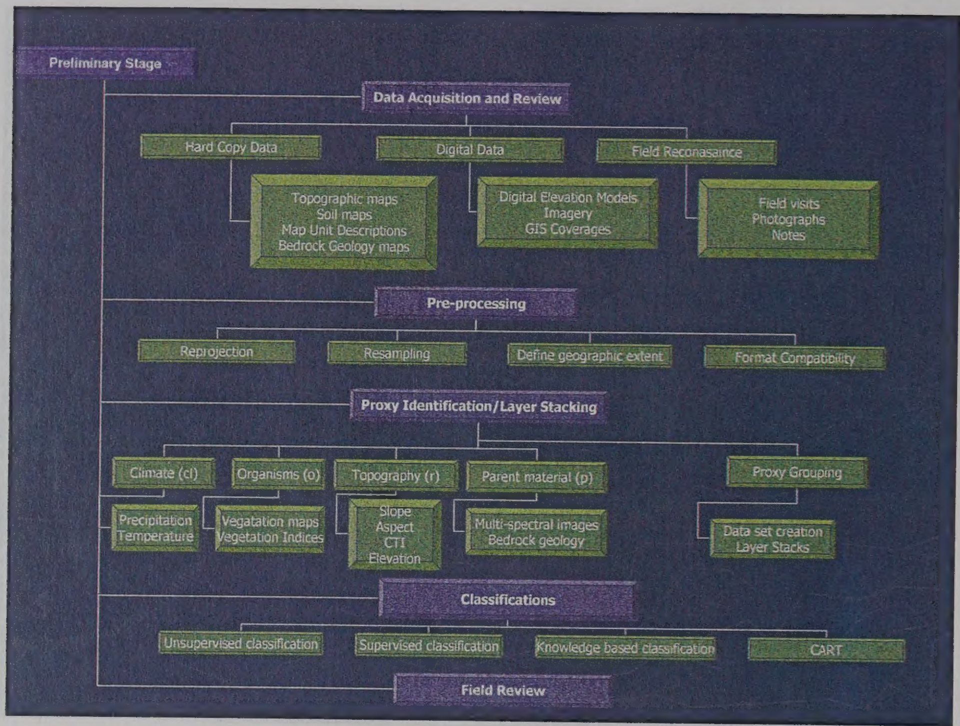
- Add soil_enhancemnt.img in ArcGIS
- Add Juniper_DOQ.img

Making Data Transparent



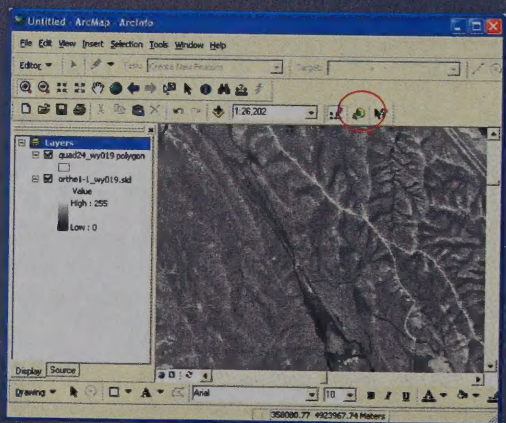
- Verify that Juniper_DOQ is the top layer
- Open *Effects* Toolbar
- Effects layer = Juniper_doq.img
- Select *Transparency* tool (looks like a cup) making transparency 35%

Manual Digitizing



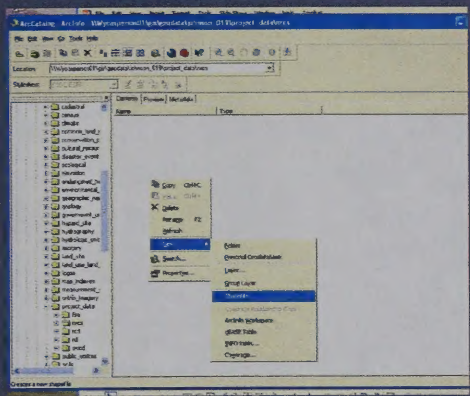
Shapefile Creation

- With ArcGIS open:



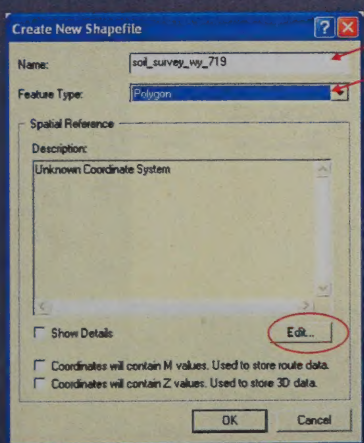
- Open ArcCatalog

Shapefile Creation



- Locate "Exercise"
  - Left click on the folder to make active
- Right click in right frame
  - Select *New*
    - *Shapefile*

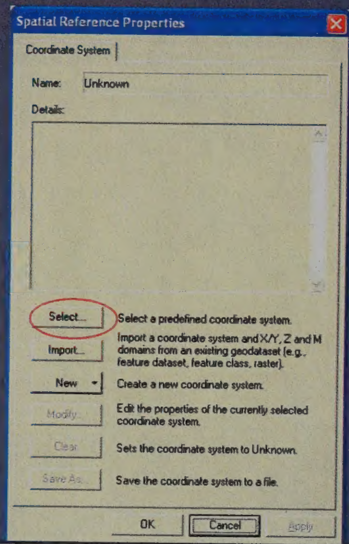
Shapefile Creation



- *Name* = soil_survey_wy_719
- *Feature type* = polygon
- Select *Edit* to define a coordinate system

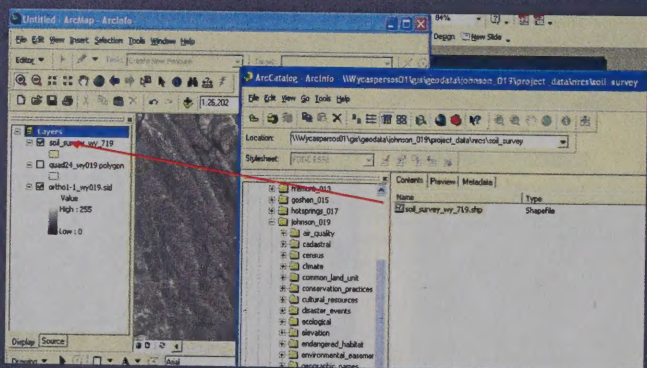
Shapefile Creation

- Click *Select*
  - *Projected...*
  - *UTM*
  - *NAD 1983*
  - *Zone 13N*
- *OK*



- Soil_survey_wy_719 should now be visible in left side of ArcCatalog

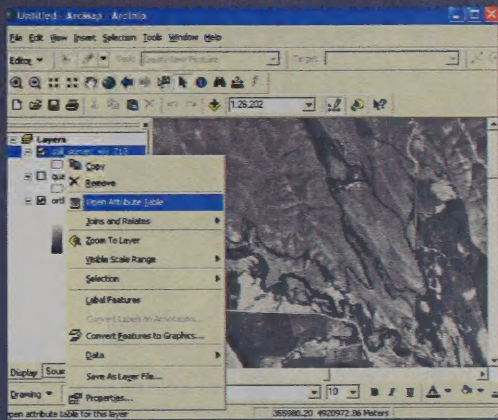
Adding Shapefiles Through ArcCatalog



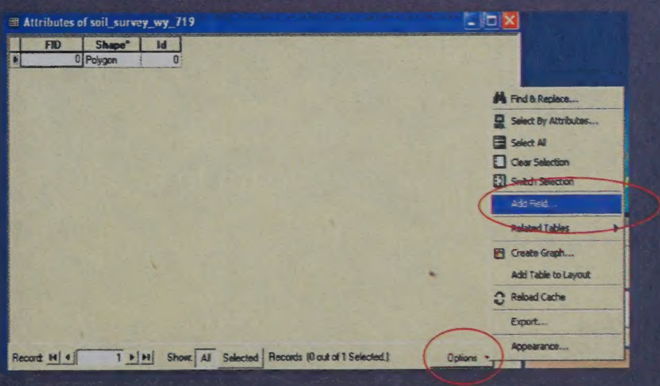
- Arrange windows so ArcGIS (left) and ArcCatalog (right) are visible
- Click on soil_survey_wy_719 shapefile
- Drag just under *Layers* in ArcGIS
- As black bar appears under *Layers* release mouse button

Adding Attributes

- Right Click soil_survey_wy_719
- Select *Open Attribute Table*



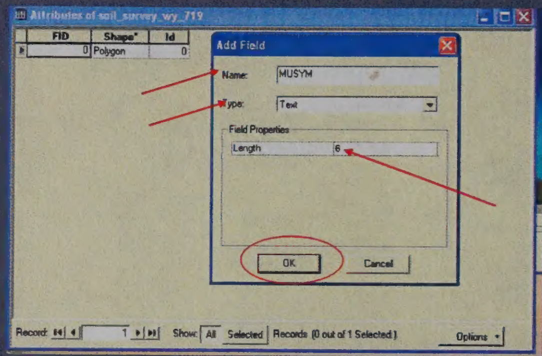
Adding Attributes



- Select *Options* pull-down
  - *Add Field*

Adding Attributes: MUSYM

- *Name* = MUSYM
- *Type* = Text
- *Length* = 6
- *OK*



Creating Polygons

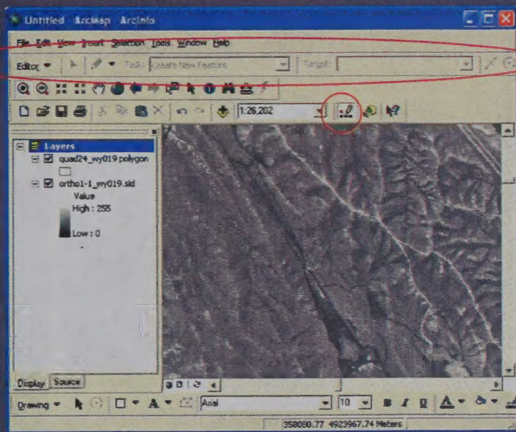
Creating features

Features can be points, lines or polygons. In this exercise, you will learn to create a polygon.

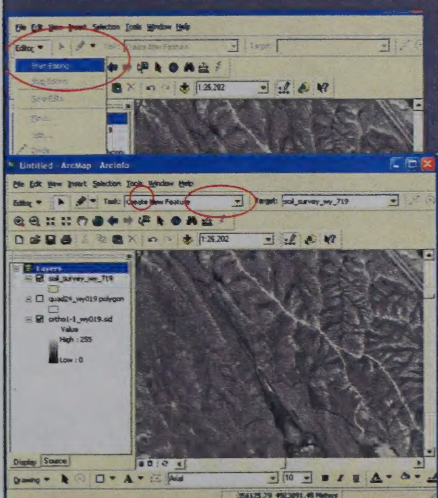
You can create lines or polygons by digitizing the vertices that make up that feature. For example, to create a square building, you would digitize the four corners.

Digitizing

- Click *Open Editor* button
  - Looks like a pencil
- Dock the *Editor Toolbar* so that its full extent can be seen

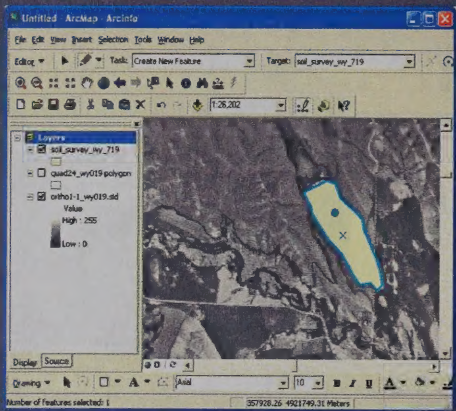


Digitizing



- On *editor* pull down on the toolbar
  - Select *Start Editing*
- *Task* = Create new feature
- Select *Sketch Tool*
  - Pencil
- *Target* = soil_survey_wy_719

Digitizing

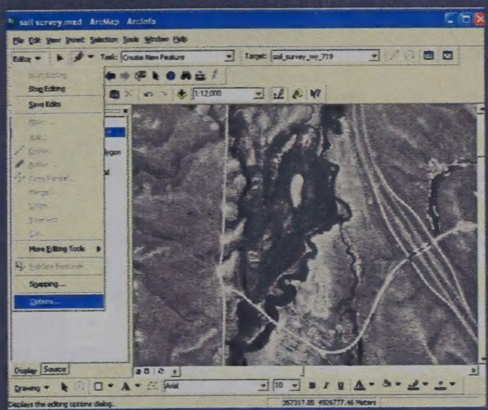


- Single click to begin a polygon
- Click to change directions/add vertices
- Lines indicate progress
- Double click to close the polygon
- Selected Polygons will have a cyan border

Stream Mode Digitizing (Streaming)

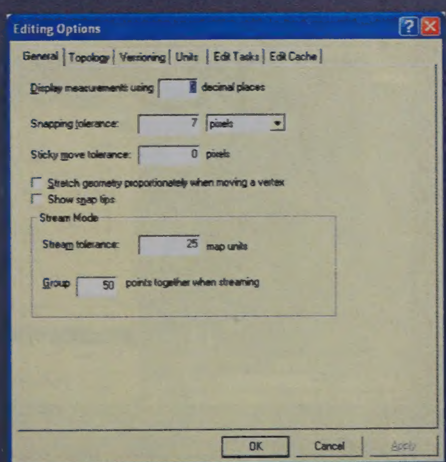
- In streaming digitizing, ArcMap automatically adds vertices at a specified interval (stream tolerance).
- Specify the number of streaming vertices you want to group together, telling ArcMap how many vertices will be deleted when you click *Undo.*
    - For example, if you set this number to 20 and click the Undo button digitizing a feature, ArcMap deletes the last 20 digitized vertices from your feature.

Streaming



- Verify that *edit* mode is on
- Select *Editor*
  - *Options*

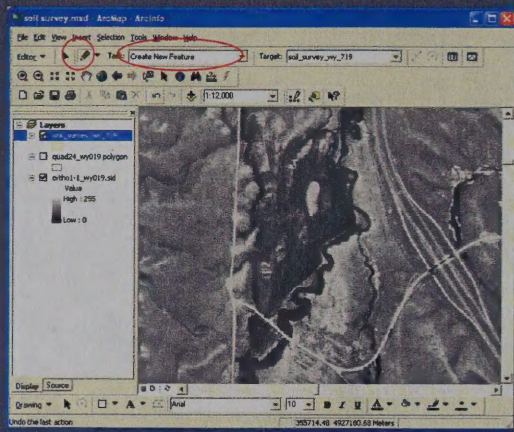
Streaming



- *Display...=* 3
- *Snapping* = 5 map units
- *Sticky move* = 0
- *Stream tolerance* = 25 (map units = meters)
- *Group* = 50
- *OK*

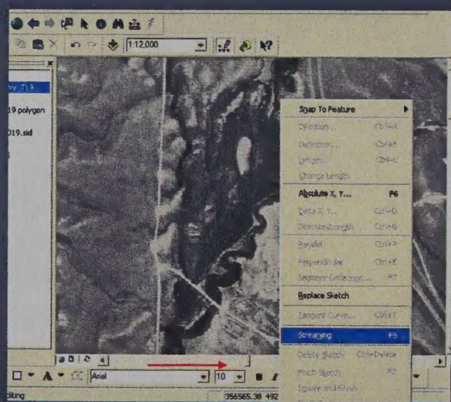
Streaming

- Select *Sketch Tool*
- *Task* = Create new feature
- *Target* = Soil_survey_wy_719

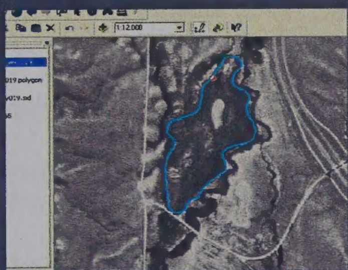


Streaming

- Right click in map area
  - Select *Streaming*
- OR hit *F8* as a shortcut to turn streaming on and off

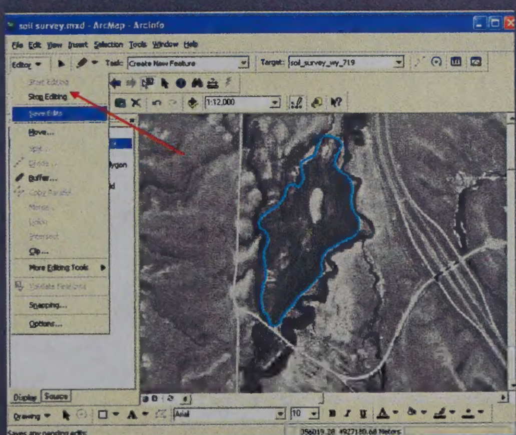


Streaming



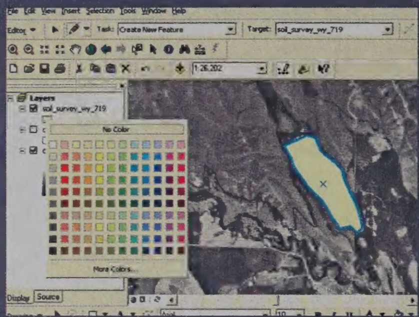
- Single click to begin
- Vertices are automatically placed
- Double Click to close the polygon

When to save



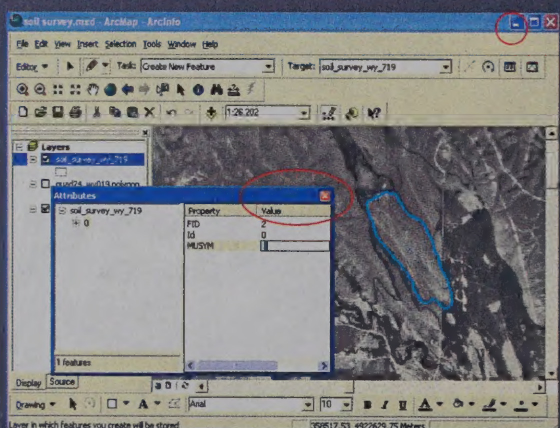
- IF you are happy with the results
  - Select *Editor*
    - *Save Edits*
- If unhappy
  - *Undo*
  - or *Stop Editing* without saving changes and restart

Polygon Symbology



- Right Click Soil_survey_wy_719
  - *Properties*
  - *Symbology*
  - *Fill Color =* Hollow
  - *Outline color =* yellow
  - *Outline width = 1.0*
  - *OK*

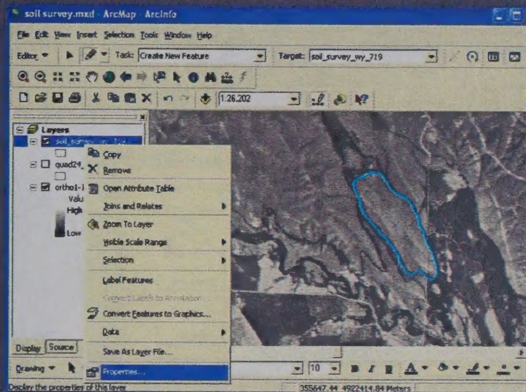
Attributing Polygons



- Click *Attribute* button on editor
  - Box appears for the selected map unit
  - Input *223* for MUSYM
  - Hit *Enter*

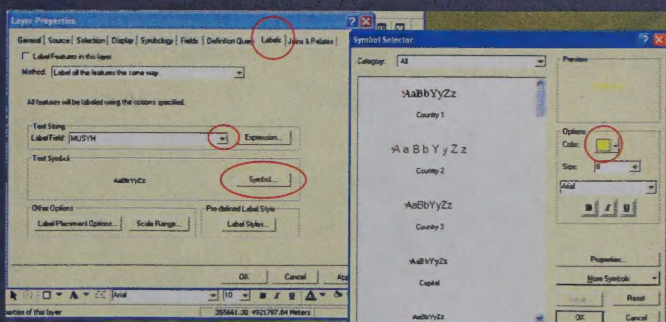
Labeling

- Right click soil_survey_719
  - Go to *Properties*



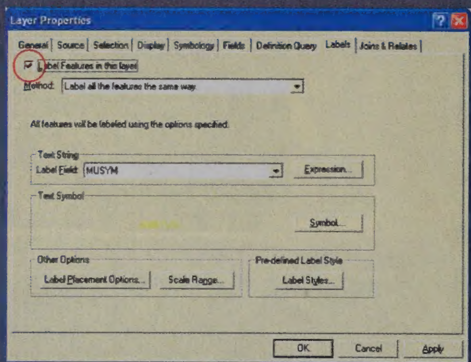
Labeling

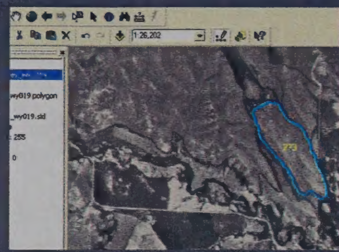
- Click on the *Labels* tab
  - Change *label field* to "MUSYM"
  - Click *symbol*
  - *Color* = yellow
  - *Size* = 14



Labeling

- On *General* tab, check the box to *Label Features in this layer*



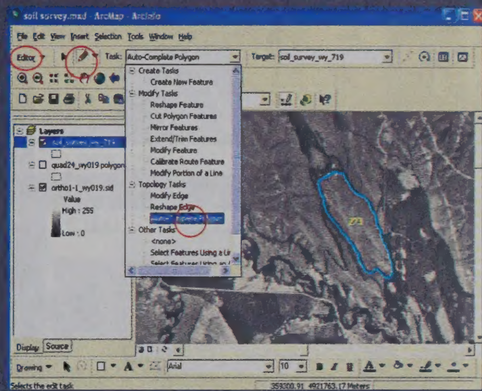


Appending Polygons

- Add a polygon to an existing polygon.
    - polygons share a common boundary, yet the user does not want or need to re-digitize that shared line.
- To append polygons in geodatabases and shapefiles, use the *Auto-Complete Polygon* task.

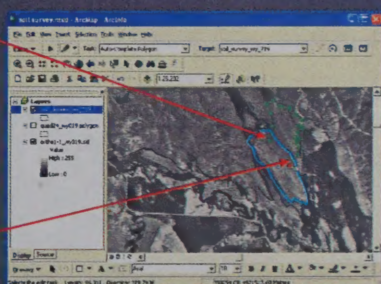
Appending Polygons

- *Start Editing*
  - On *Editor* toolbar pull down
  - Choose *Auto-Complete Polygon*
  - Select your sketch tool

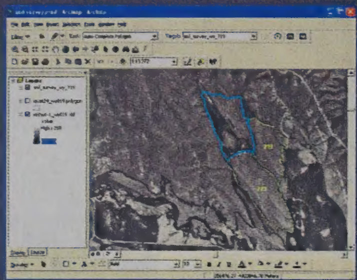


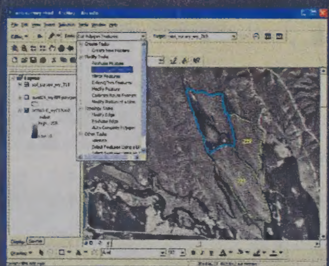
Appending Polygons

- Click once inside neighbor polygon
- Digitize new line outside of the polygon
- Finish by double clicking inside the polygon that you are appending to
  - The shared boundary doesn't need to be digitized again



Splitting Polygons

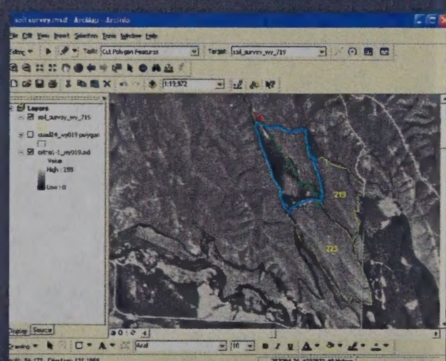




- Select the polygon you will split using the *Selection Tool*
- Select *Cut Polygon Features* task from the *editor* pull down menu

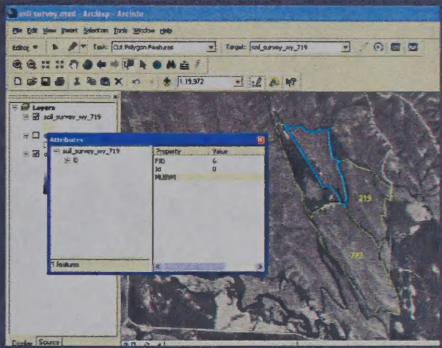
Splitting Polygons

- Single click outside the polygon
- Split it by digitizing a line
- Double click on the opposite side of the polygon



Splitting Polygons

- Select each polygon individually
- Attribute the polygon
  - MUSYM

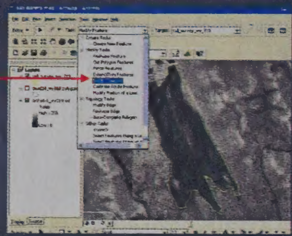


Modifying Existing Polygons

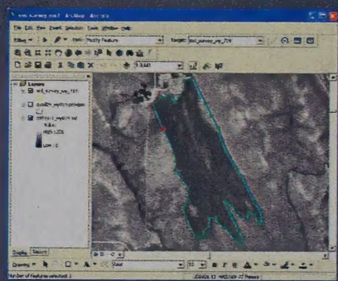
- Zoom into the area that you will correct
- Verify that you are in *Editing* mode

Modifying Polygons

- Choose *Modify Feature* from the *Editor* menu



- Using the *Selector Tool* identify polygon to modify

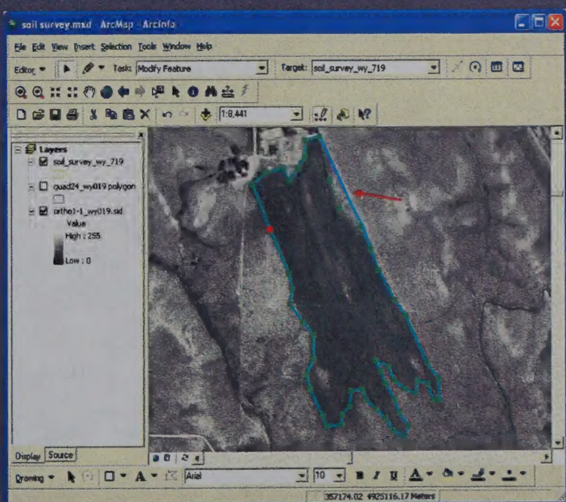


Caution

- It is very easy to move the entire polygon when attempting to edit a vertex. If you do you will ruin the topology of your file.

Modifying Polygons: Moving Vertices

- Use the *Editor tool* (black arrow)
- Click on and drag a vertex to move it
- Right click on line to add vertices



The original line work will be displayed in cyan after you move a vertex.

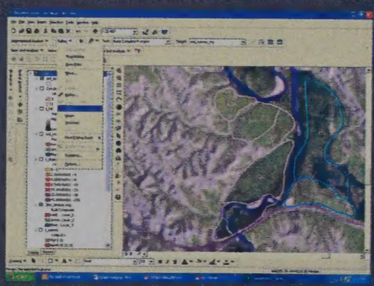
This will assist you in remembering where you have moved vertices.

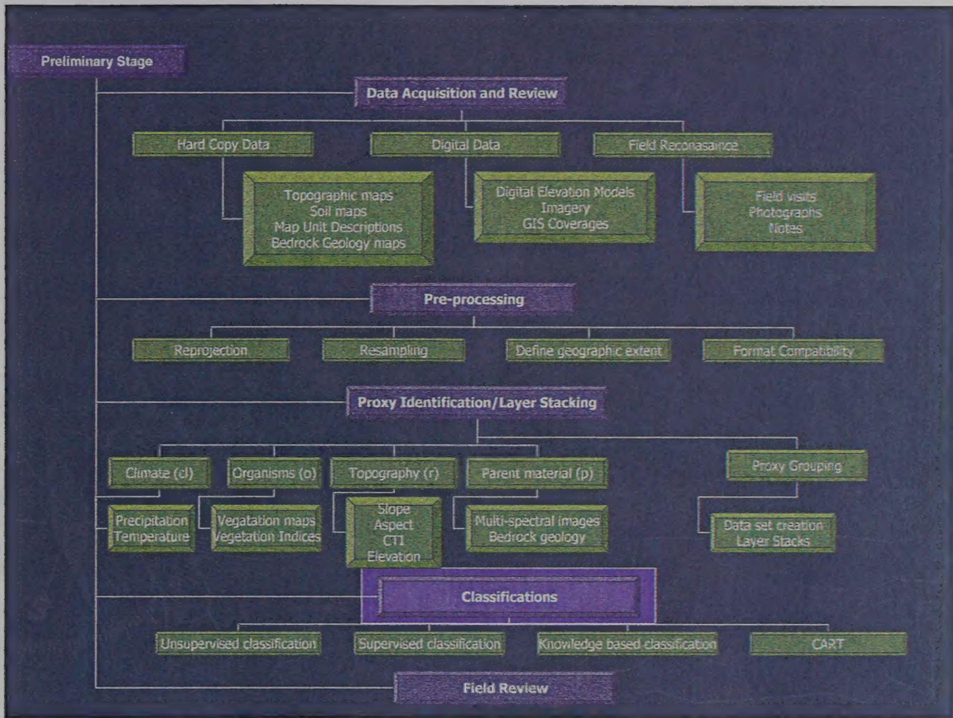
Alternate Editing

- Instead of moving individual vertices
  - Auto complete a small polygon around the area you'd like to change
  - Merge the new polygon with the old

Merging Polygons

- Select adjacent polygons using the *Selector* tool (click and drag)
- Under *Editor*
  - *Merge*
- *Merge Window* appears
  - From list select polygon to append to (it will blink when you select it)
  - *OK*

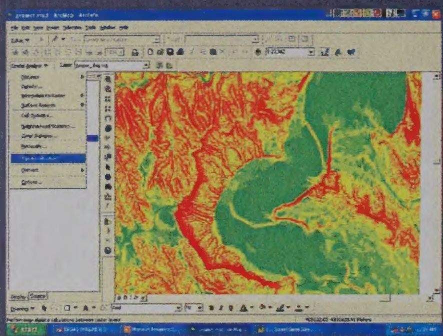




Automated Creation of Polygons:

Classifying Data in ArcGIS

Query Data With Raster Calculator

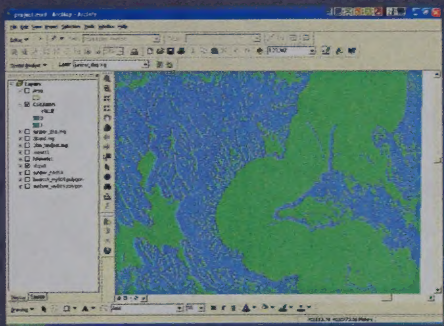


- Open *Spatial Analyst*
  - Open *Raster Calculator*
  - Make sure J_slope is added to your project

Querying Data with Raster Calculator

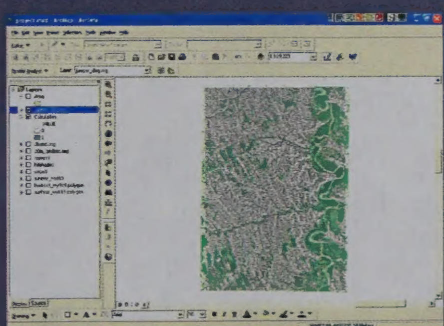
- In *Raster Calculator*
  - Enter
  J_slope <= 10
  - *Click Evaluate*

Calculation

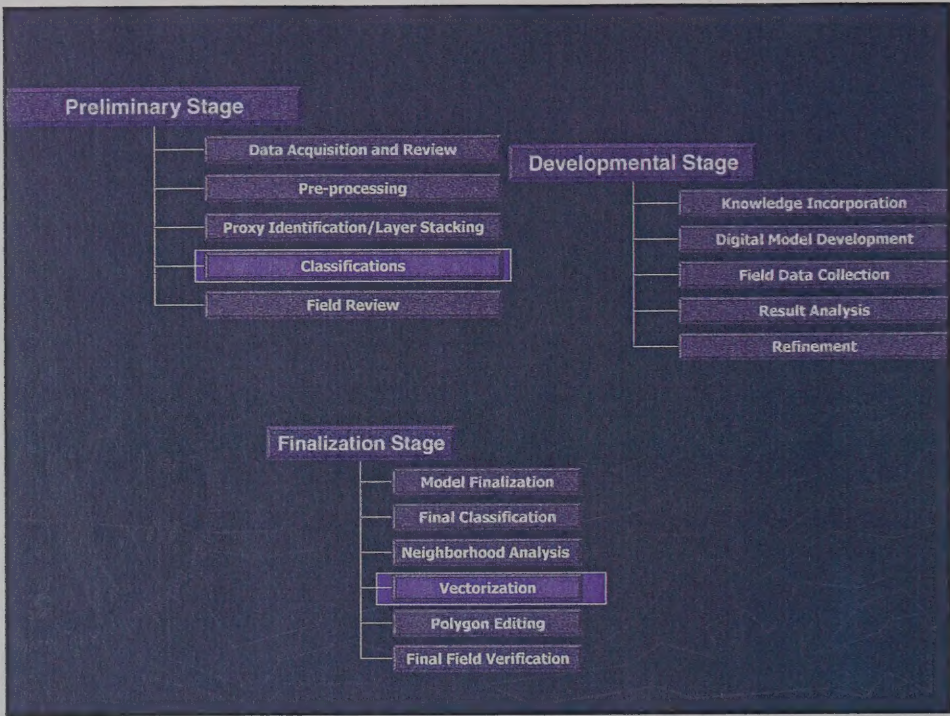


- To view only areas that are less than 10% slope
  - Double click the *0* box in the *TOC*
  - Enter *no color*

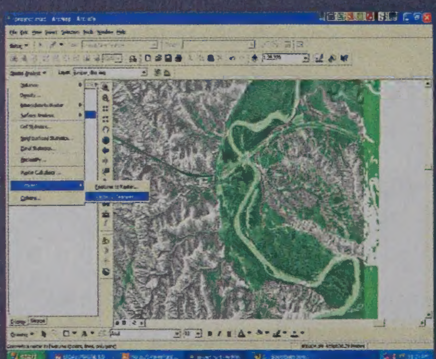
Displaying Queried Data



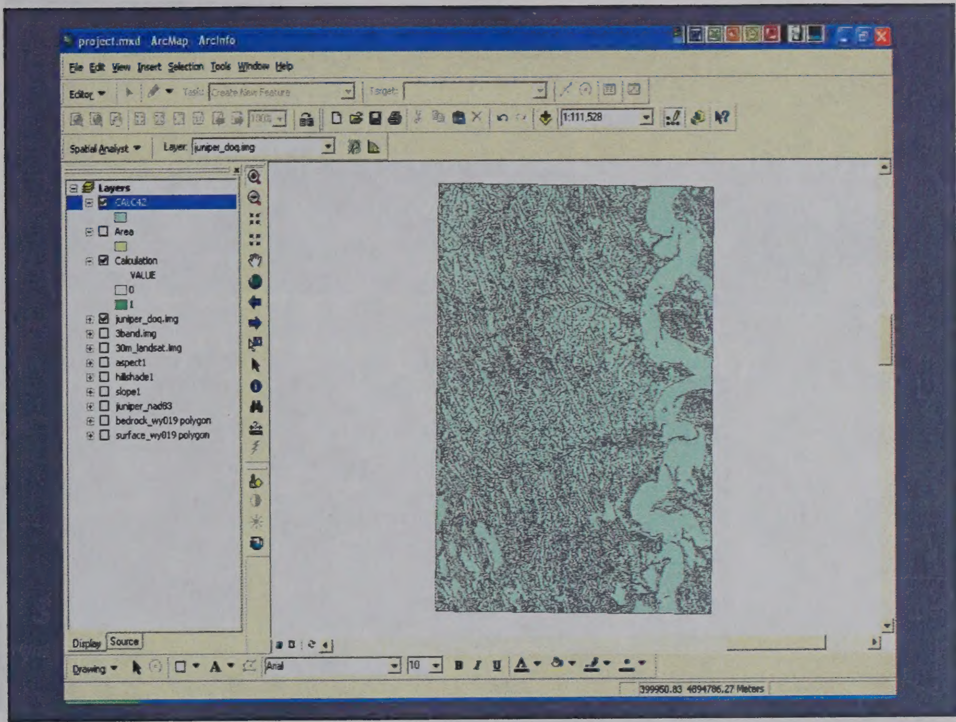
- Make Calculation transparent by 50% using the *transparency tool*
- Turn off all layers accept a Juniper_DOQ



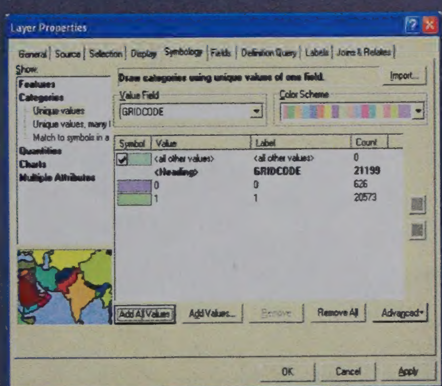
Vectorizing Data



- *Spatial analyst*
  - *Convert Raster to Feature*
  - Select calculation as the *input*
  - *Output* as lines_1
  - *Generalize*
  - *OK*

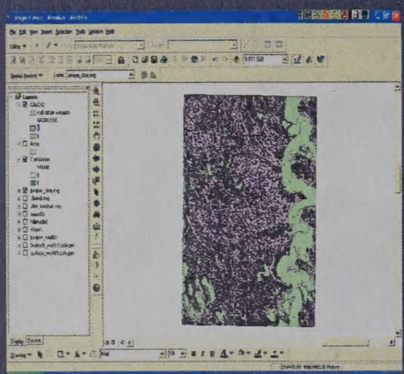


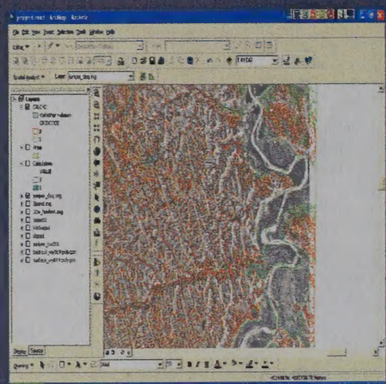
Change Attributes



- Right click lines_1
  - *Properties*
  - *Symbology*
  - *Unique value*
    - *Value field* = gridcode
    - *Add all values*
  - *OK*

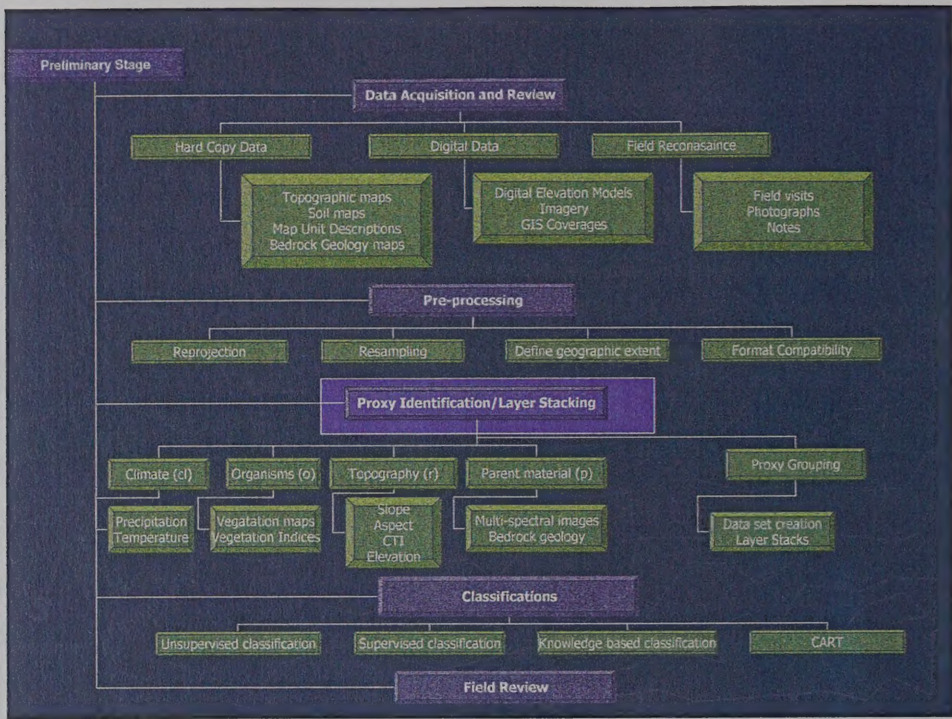
Display Options:
Polygons or Lines on Orthophotos





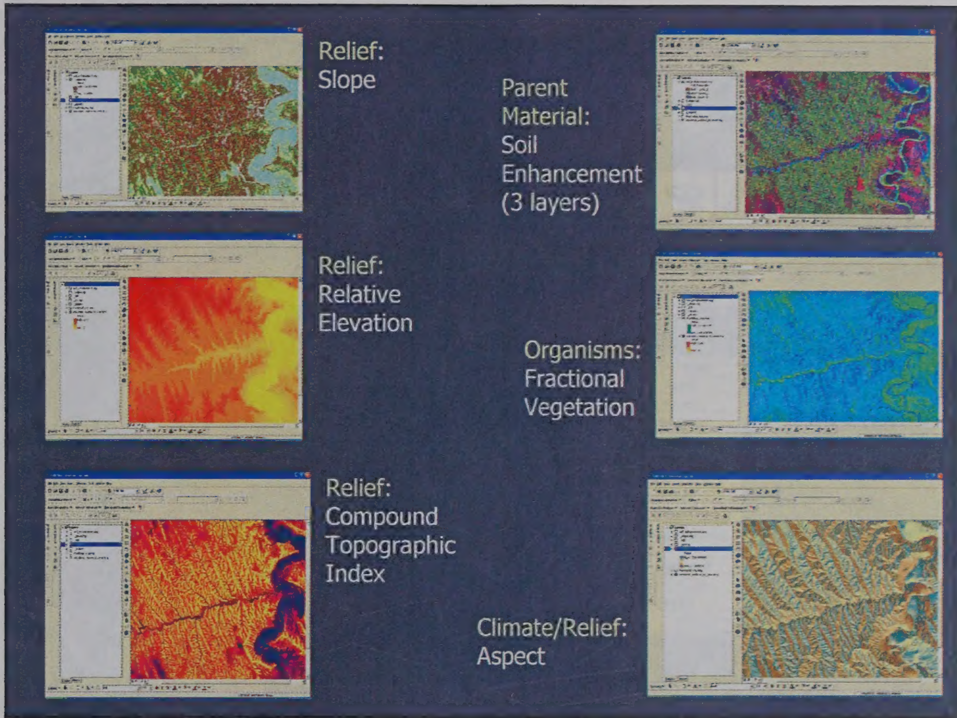
Automated Pedogenic Understanding Raster Classification

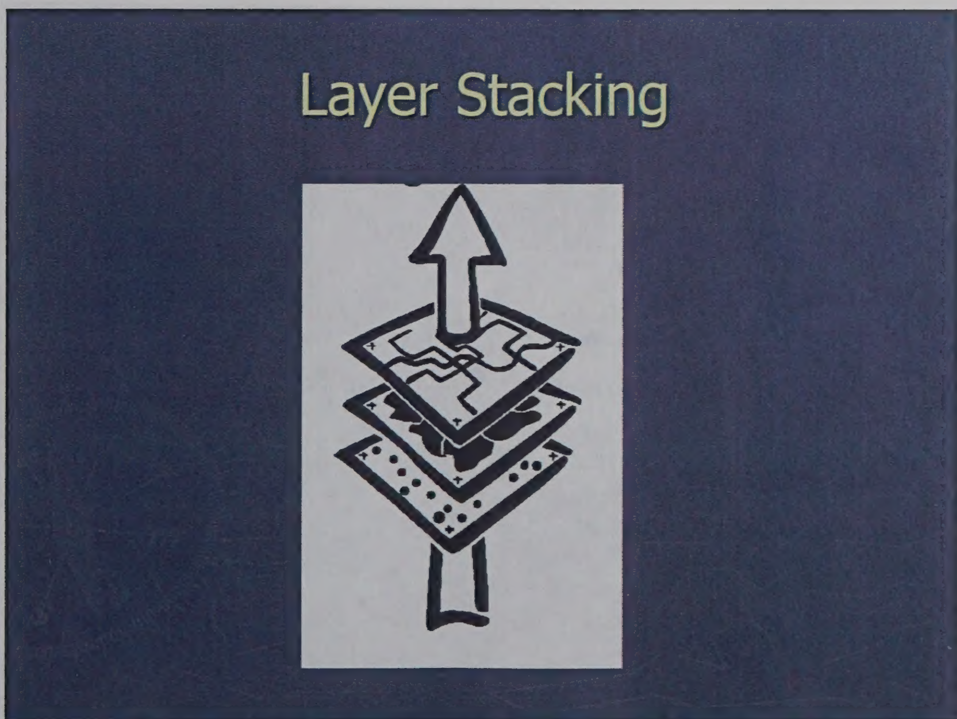
- **Preliminary Stage**
  - Data Acquisition and Review
  - Pre-Processing
  - Proxy Identification/Layer Stacking
  - Classifications
  - Field Review
- **Developmental Stage**
  - Knowledge Incorporation
  - Digital Model Development
  - Field Data Collection
  - Result Analysis
  - Refinement
- **Finalization Stage**
  - Model Finalization
  - Final Classification
  - Neighborhood Analysis
  - Vectorization
  - Polygon Editing
  - Final Field Verification



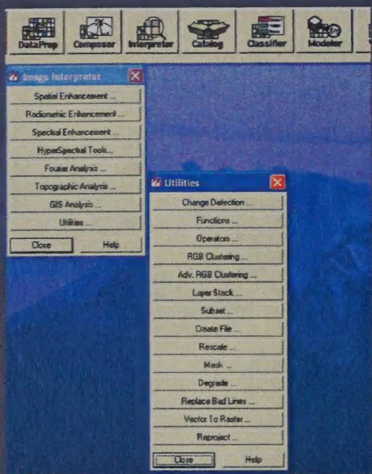
Proxy Identification

- What are the soil forming factors?
- What are possible data layer proxies?
- What proxies will be useful in our area?
- How will you determine which proxies are most valid?


Relief:
Slope
Parent
Material:
Soil
Enhancement
(3 layers)
Relief:
Relative
Elevation
Organisms:
Fractional
Vegetation
Relief:
Compound
Topographic
Index
Climate/Relief:
Aspect

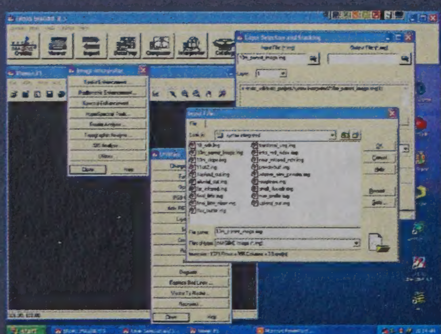

Layer Stacking

Combining Processed Digital Data: Sets of Soil Forming Factors

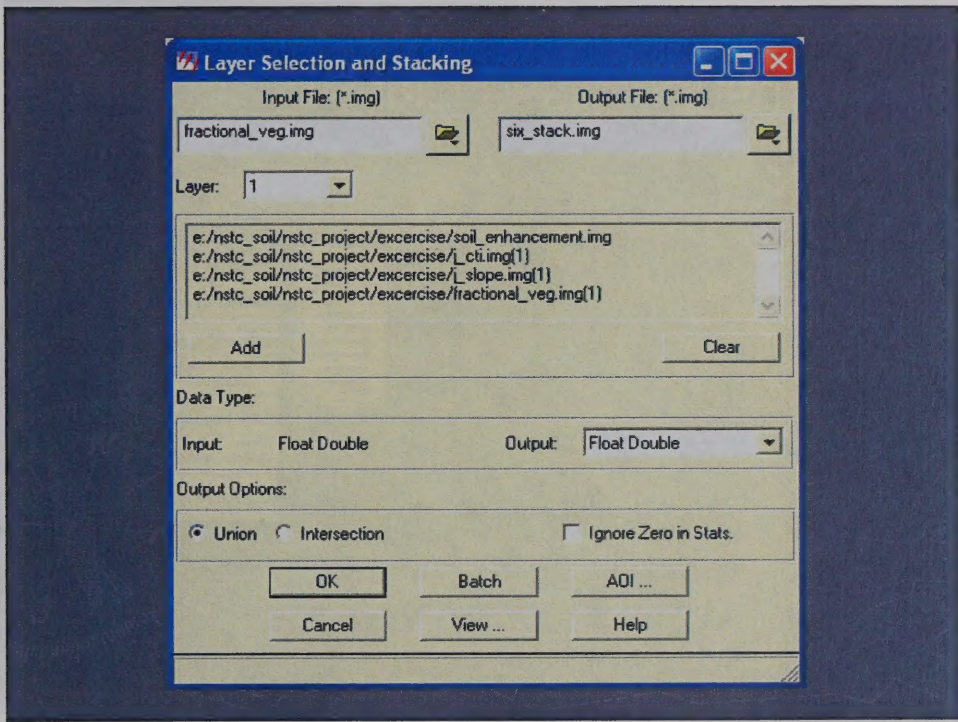


- *Image Interpreter*
  - *Utilities*
    - *Layer stack*

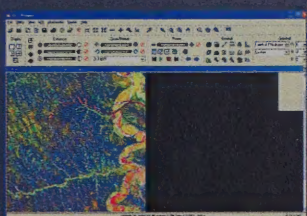
Combining Syntax Integrated Data Sets



- *Input* soil_enhancement
  - Select *all bands*
  - *Add*
- Change *Input* to J_CTI
  - Select *band 1*
  - *Add*
- Change *Input* to J_slope
  - *Band 1*
  - *Add*
- Change *Input* to Fraction_veg
  - *Band 1*
  - *Add*
- *Output file* = six_stack



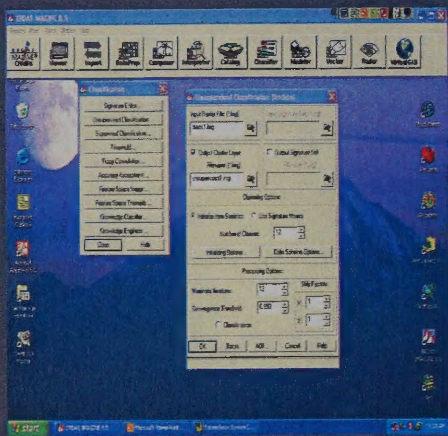
Signatures and Feature Space



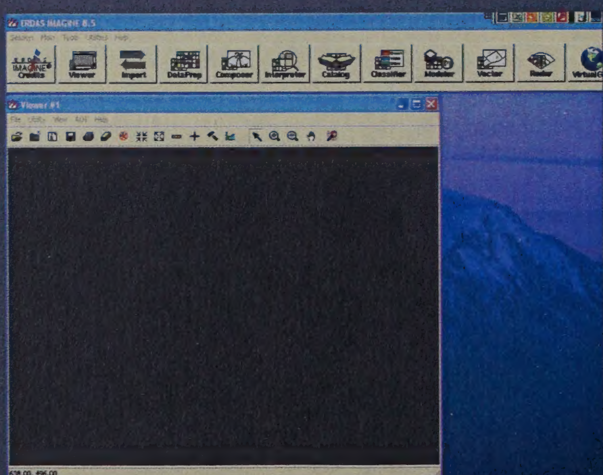
- Each point has a unique signature
- Feature space location
- Groups of likeness
- Statistical classification

Unsupervised Classification

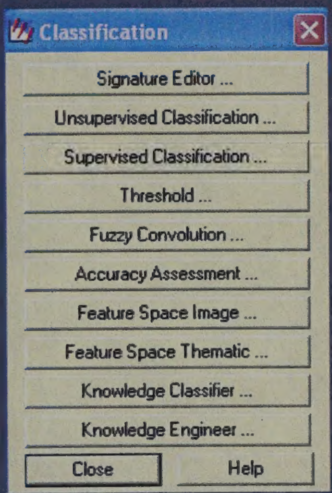
- Unsupervised Classification
  - Isodata clustering
    - Clustered in "feature" space
    - Convergence
    - Input classes
  - Unbiased, data-driven
  - Recognize patterns



Classification Options in Erdas Imagine



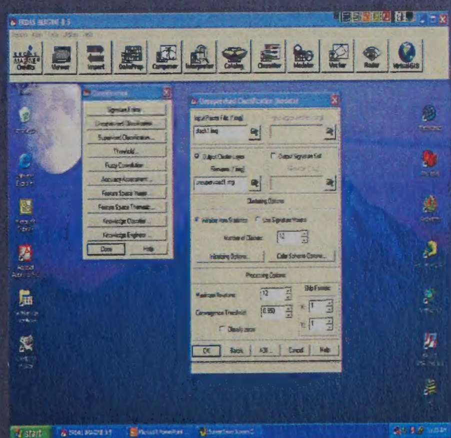
Unsupervised Classification



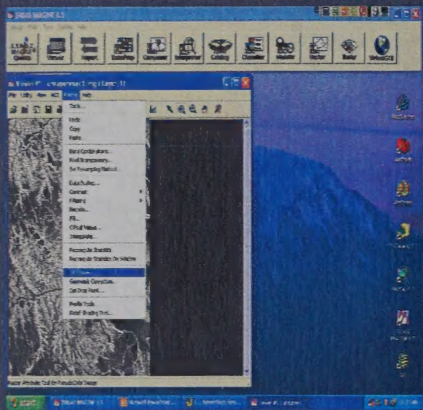
- In Imagine
- Select *Classifier*
  - *Unsupervised Classification*

Unsupervised Classification

- *Classifier*
  - *Input* = six_stack
  - *Output* = unsupervised_1
  - Isodata clustering
  - *Class number* = 12
  - *Convergence* = .95
  - *Iterations* = 20

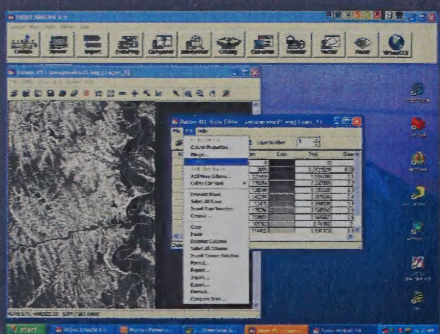


Open Classified Image



- Open Imagine Viewer
  - *Add*
  - *Raster Layer*
  - Unsupervised 1

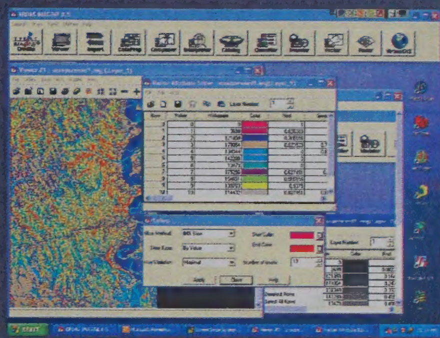
Adjust Raster Attributes



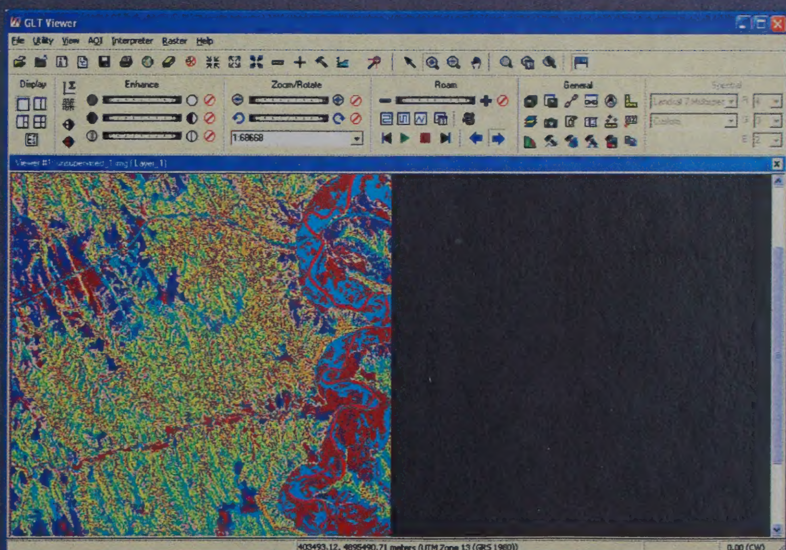
- In the Viewer select
  - *Raster*
    - Select *Attributes*
    - *Edit Colors*

Adjusting Attributes

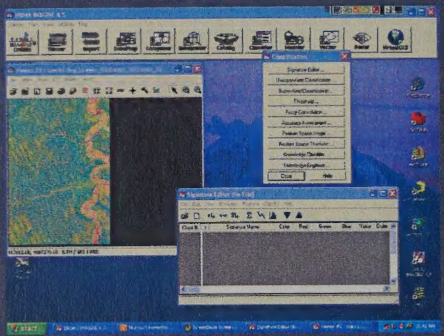
- When the color palate pulls up hit *apply*
- Minimize the two small windows



What did we accomplish?

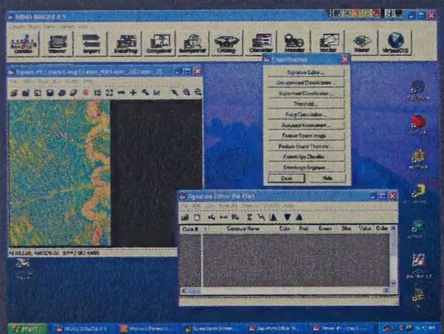


Supervised Classification



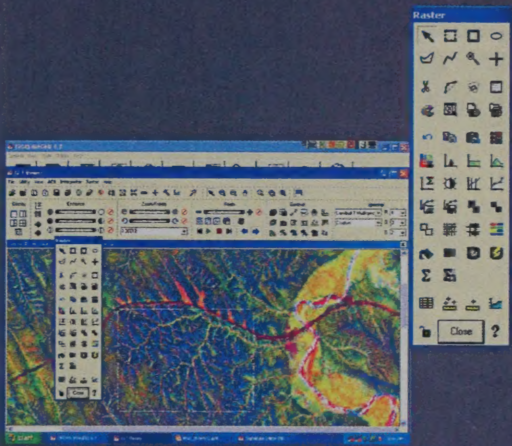
- Supervised Classification
  - Select training areas
    - Neighboring soil map
    - Class center (means)
    - Pixel ID from Euclidean distance formula
  - Biased, user-driven
  - Garbage in, garbage out

Supervised Classification

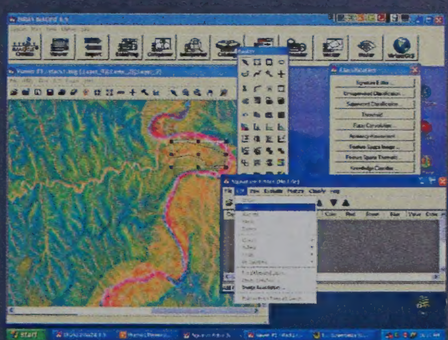


- Open *Classifier*
  - *Signature Editor*
- Open six_stack in an Imagine viewer

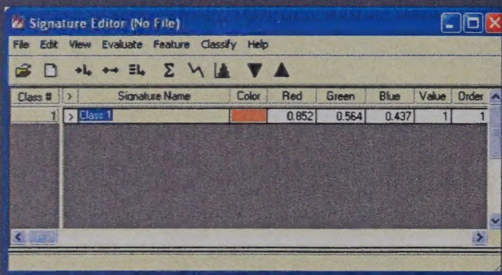
Raster Tools

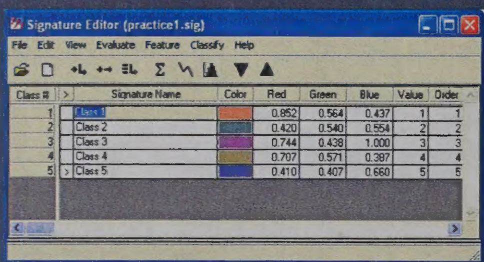


- Open *Raster tools*
  - Select the *AOI polygon tool*
  - Create a polygon on the classified image that defines an area
    - This is a "Training area"



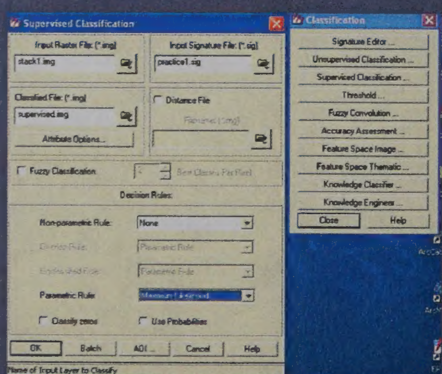
- *Signature Editor*
  - *Edit*
    - *Add*
- Your class signature is now added





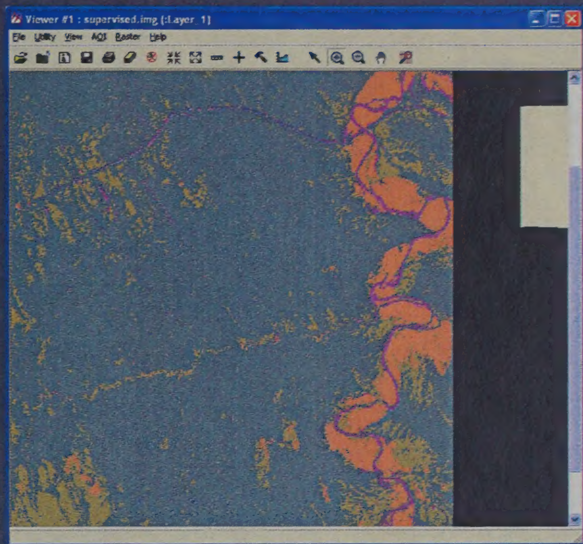
- Save the signature file as
  - Supervised_sig
  - Continue adding signatures to your signature file
  - Save Signature file

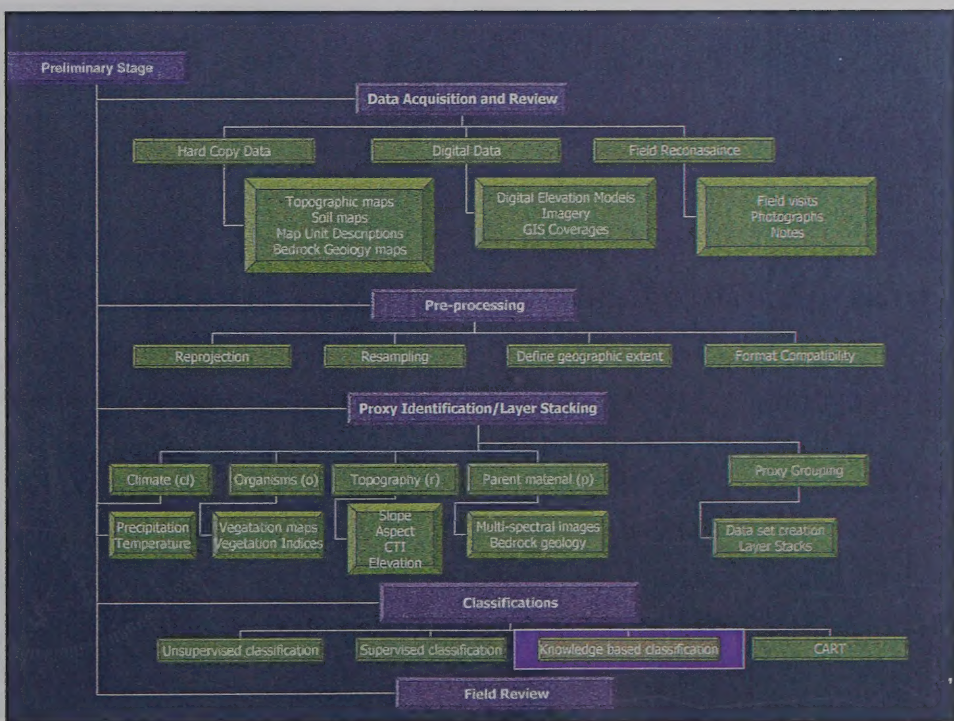
Supervised Classification



- Under *Classifier* Select
  - *Supervised Classification*
  - *Input raster* = six_stack
  - *Signature file* = supervised_sig
  - *Classified file* = supervised.img
  - Accept other defaults

Open Classified Image in a Viewer



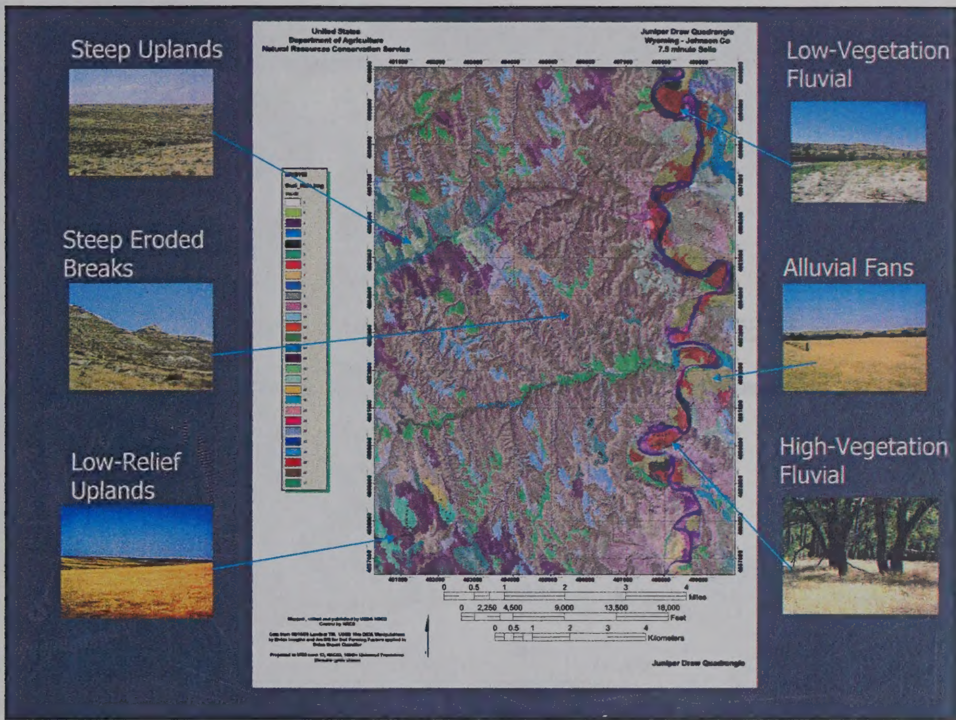


Knowledge Based Classification

- Simple knowledge-based classification (Rule-based)
  - Slope breaks
  - Vegetation
  - Parent material

Knowledge-Based Classification

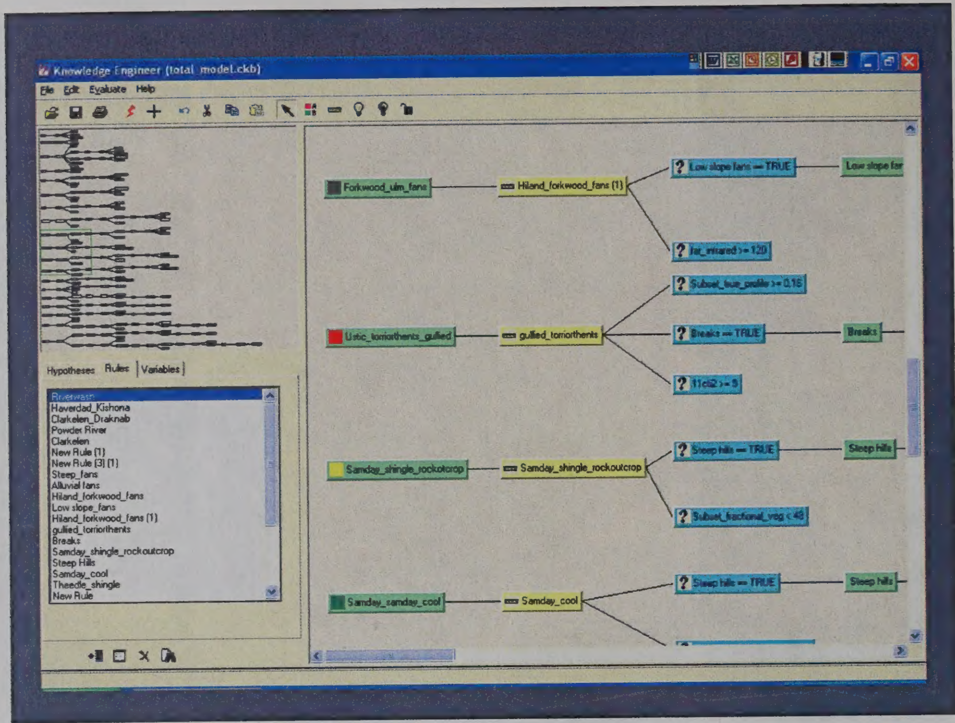
- Recognized patterns
  - Unsupervised
  - Supervised
- Conceptual Models of Soil Formation
  - Digital proxies
  - Recording quantifiable relationships
    - Soil map unit concepts



Creating Hypotheses: Soil Map Unit Concept

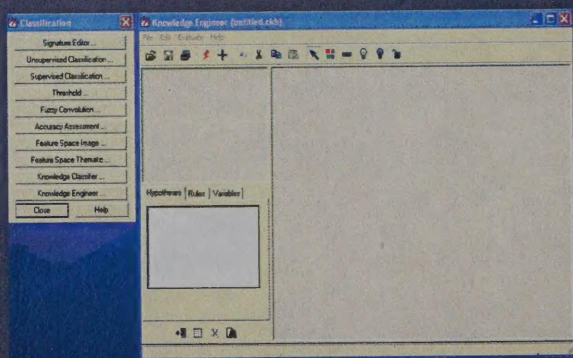
- Fluvial
  - Near Powder River
  - Low Relief
- Breaks
- Alluvial Fans
- Uplands

Knowledge-Based Classification in Imagine



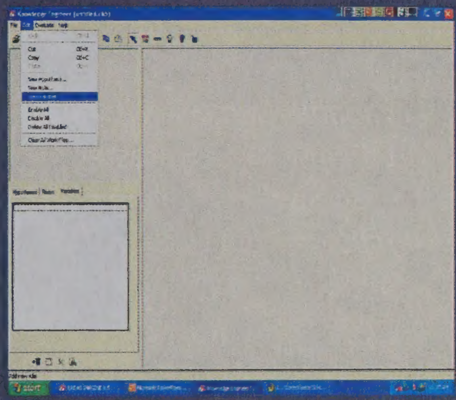
Knowledge Based Classification

- *Classifier*
  - Open *Knowledge Engineer*

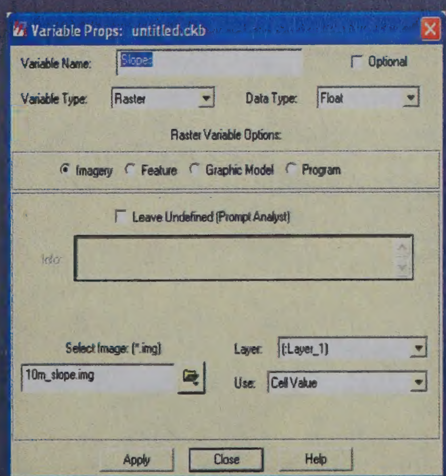


Adding Variables

- Under *Edit*
  - Select *New Variable*



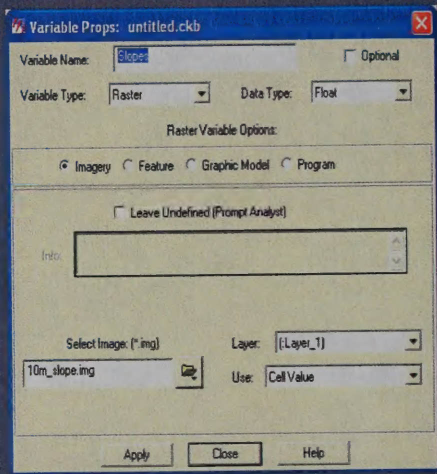
Adding Variables: Relief Slope



- *Variable Name* = slopes
- *Variable type* = Raster
  - Imagery
- *Input* = J_slope.img
- *Apply*
- *Close*

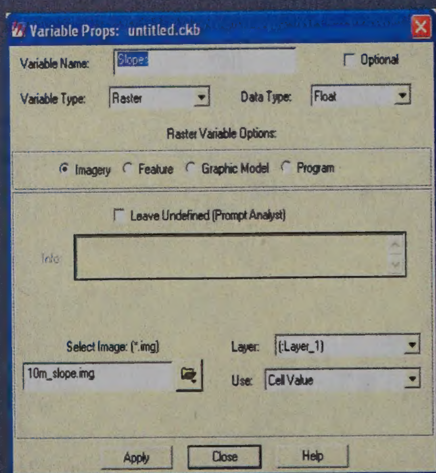
Adding Variables: Relief Wetness Index (CTI)

- *Variable Name* = Wetness
- *Variable Type* = Raster
  - Imagery
- *Input* = J_CTI
- *Apply*
- *Close*



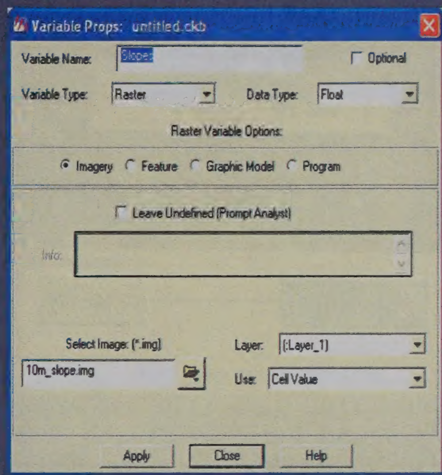
Adding Variables: Relief Relative Elevation

- *Variable Name* = Elevation
- *Variable Type* = Raster
  - Imagery
- *Input* = Elevation_relative_to_river
- *Apply*
- *Close*



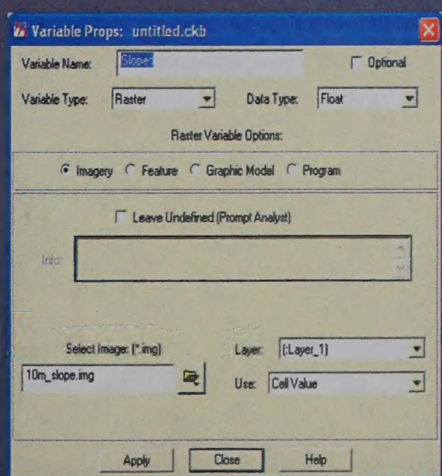
Adding Variables: Organisms
Fractional Vegetation Index (FVI)

- *Variable Name =* Vegetation
- *Variable type =* Raster
  - Imagery
- *Input =* Fraction_veg
- *Apply*
- *Close*

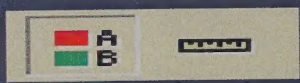


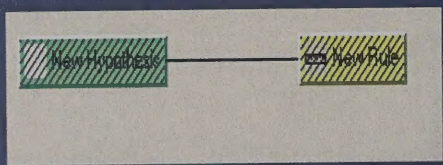
Adding Variables: Parent Material
Soil Enhancement - Ferrous Iron

- *Variable Name =* Iron
- *Variable Type =* Raster
  - Imagery
- *Input =* soil_enhancement
  - *Layer 2*
- *Apply*
- *Close*



Creating Hypotheses and Rules





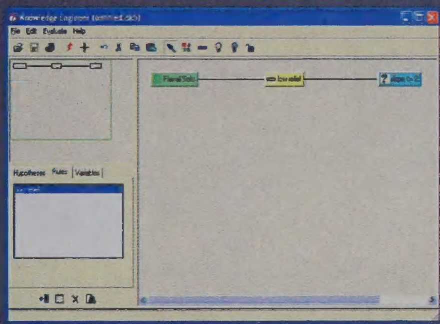
- Select hypothesis tool (looks like AB) and place a green box – double click to name
- Attach a rule using the tool that looks like a ruler (place ruler on right half of the hypothesis box) – double click to define the rule

Define the Hypothesis

- Hypothesis 1 - Fluvial Soils
  - Low relief
  - Occur near streams
- Double Click *New Hypothesis* Box
  - *Name* = Fluvial Soils
    - *Enter*
  - *Color*
    - *Specify* = Green
  - *Apply*
  - *Close*

Define the Rule

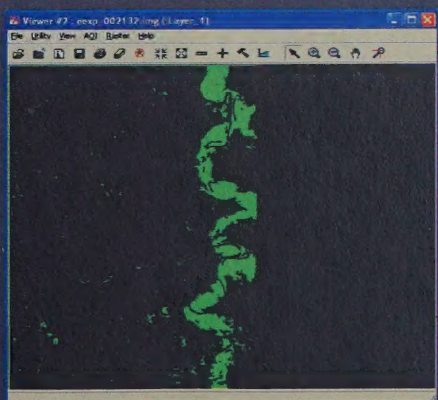
- Double click N*ew Rule*
  - *Name* = Low Relief
  - *Variable* as slope
  - Click in *Relation* and change to <=
  - Click in *Value*
    - Select *Other*
    - *2*
  - Hit *Apply* then *Enter*



Running a test classification

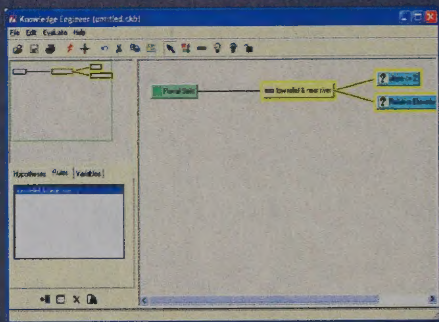
- Locate the run button (lightning bolt)
- Accept defaults… Run it

- RESULTS
  - Slope <= 2%
  - Entire study area!
- Refine the rule (model)



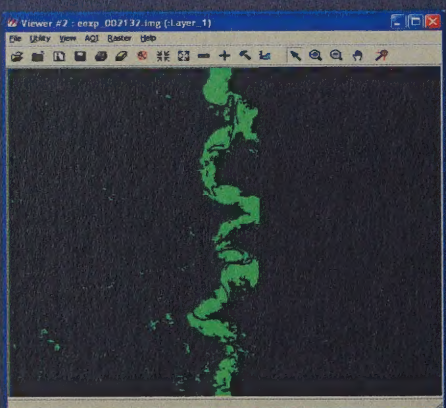
Refine the Rule

- Double click *Low Relief*
  - *Name* = Low Relief & Near River
  - Add 2nd *Variable* Relative Elevation
  - Click in *Relation* and change to <
  - Click in *Value*
    - Select *Other*
    - *5*
  - Hit *Apply* then *Enter*

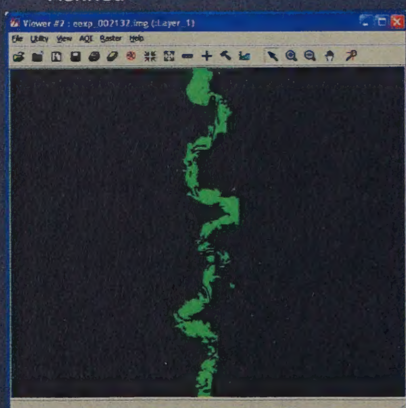


Results of Refined Classification

Initial



Refined

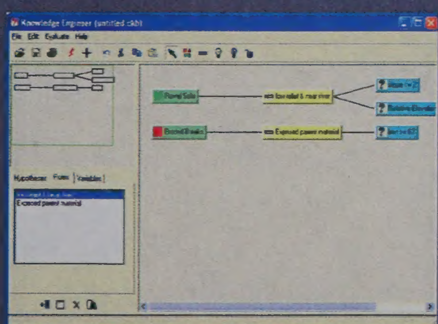


Define Additional Hypotheses

- Hypothesis 2 – Eroded Breaks
  - Exposed parent material
  - Steep
- Double Click *New Hypothesis* Box
  - *Name* = Eroded Breaks
    - *Enter*
  - *Color*
    - *Specify* = Red
  - *Apply*
  - *Close*

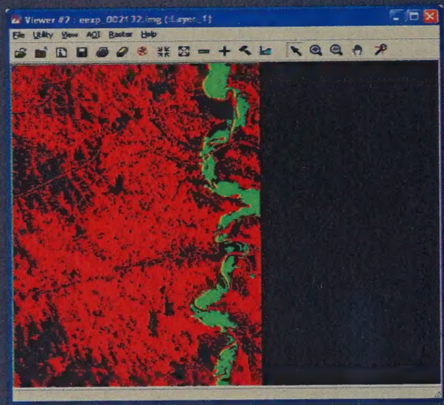
Define the Rule

- Double click *New Rule*
  - *Name* = Exposed Parent Material
  - *Variable* = Iron
  - Click in *Relation* and change to >=
  - Click in *Value*
    - Select *Other*
    - *67*
  - Hit *Apply* then *Enter*



Running a test classification

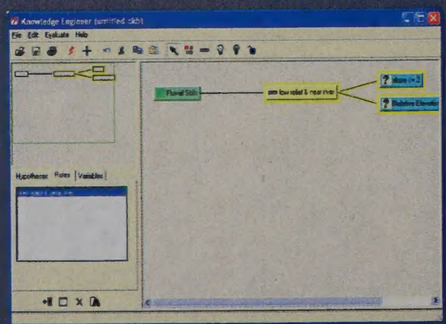
- Locate the run button (lightning bolt)
- Accept defaults... Run it



- RESULTS
  - Iron > 67
  - All slopes!
- Refine the rule (model)

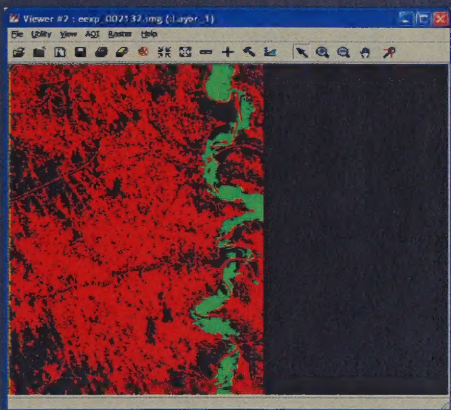
Refine the Rule

- Double click *Exposed parent material*
  - *Name* = Exposed parent material & steep
  - Add 2nd *Variable* Slope
  - Click in *Relation* and change to >
  - Click in *Value*
    - Select *Other*
    - *10*
  - Hit *Apply* then *Enter*

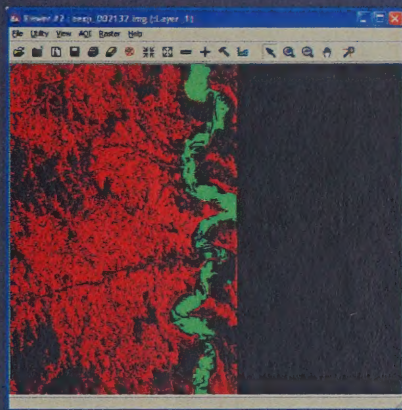


Results of Refined Classification

Initial

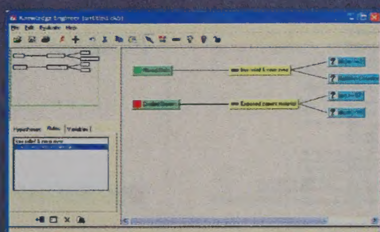


Refined

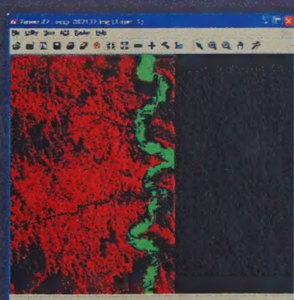


Knowledge Classification

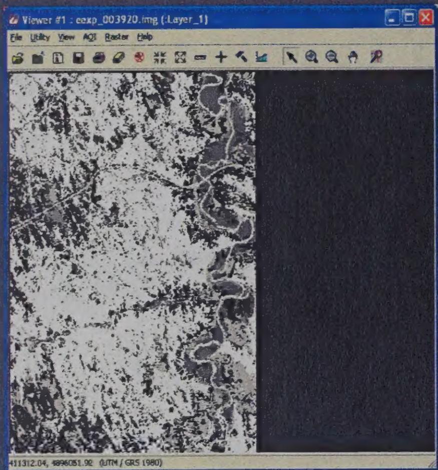
- Save your model as "know_1"



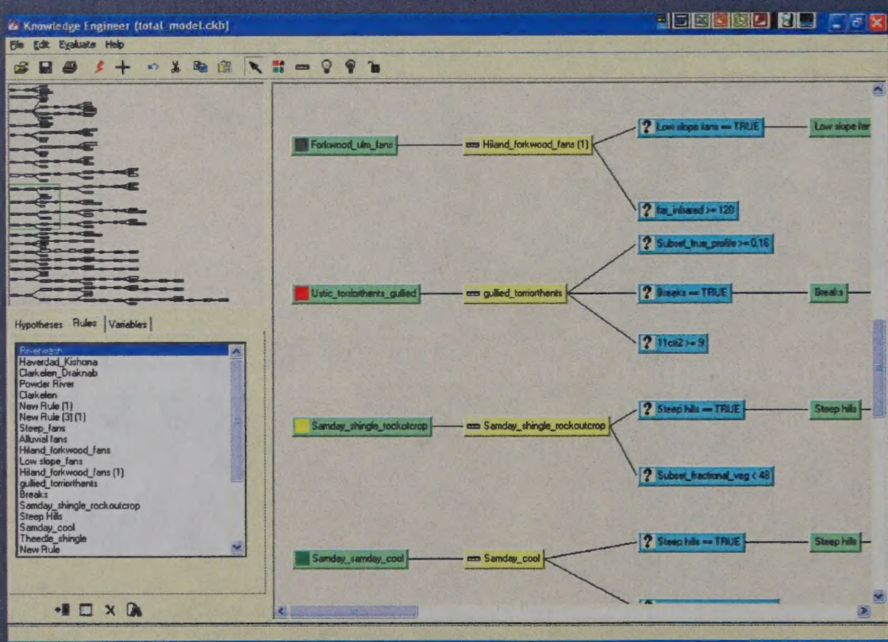
- Run the model final classification
  - *Classifier*
    - *Knowledge Classifier*
    - Knowledge Base = Know_1



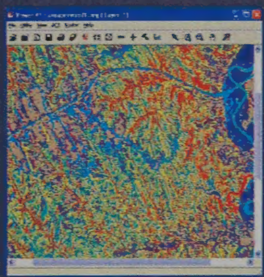
Simple Rule Based Classifications



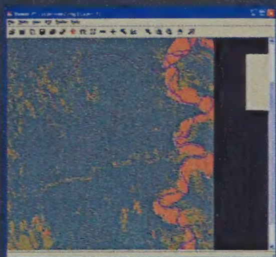
- Slope Breaks
- Vegetation levels
- Simple combinations of supervised and unsupervised images

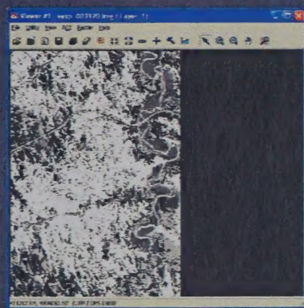


Field review



- Advantages of:
  - Unsupervised?
  - Supervised?
  - Knowledge based?



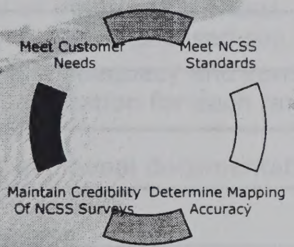


EVALUATION

Advanced Technology in Soil Mapping

Evaluation

Evaluation Importance



Objective:

- Given the ongoing project conditions and access to the required information,
  - Select and acquire spatial, attribute, point, and polygon data needed to perform the evaluation.
  - Use appropriate techniques to evaluate the data for consistency, adequate documentation, and accuracy.

Objective: (cont.)

- The line work will conform to predicted soil-landscape boundaries, map unit composition will accurately reflect soil-landscape relationships, and deficiencies in documentation will be identified.

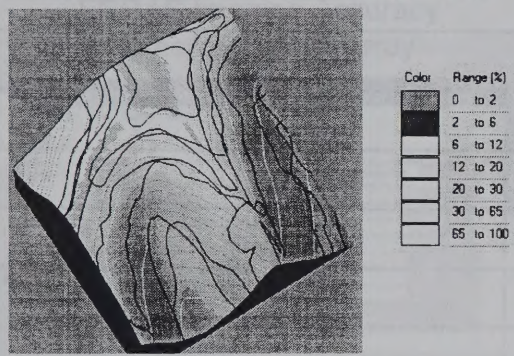
Data Acquisition

- Soil Survey Update
  - Gather the appropriate data layers that are available to evaluate the soil map.
  - Preprocess the data layers – clip, join, merge, re-sample, re-project, enhance, rectify, do ratio development
- New Mapping
  - Use the same GIS/remote sensing data layers that were used for mapping

Line Work Evaluation

- Retrieve GIS based soil map
  - Edge matches within and between polygons
  - All polygons correctly labeled
  - Lines conform to GIS/remote sensing indicators of soil/landscape relationships

Comparison with the conventional soil polygon maps



(source: Zhu and Burt, 2003)

Adequate Documentation

- Record all point and transect locations onto GIS based soil map
- Determine adequacy and consistency of documentation for each taxa and map unit
- Collect additional documentation as needed

Map Unit Accuracy

- Field review of point and transect data – standard operating procedure
- Overlay all point and transect data onto a soil map
  - Visually examine to see if point and transect data match the concepts of soil-landscape relationships.
  - Most simplistic approach

Map Unit Accuracy (cont.)

- Set up a stratified semi-random sampling scheme
  - Compare data points to soil map and model
- Subset point and transect data using half to refine the soil-landscape model and half to assess map unit accuracy
- Prepare error matrix

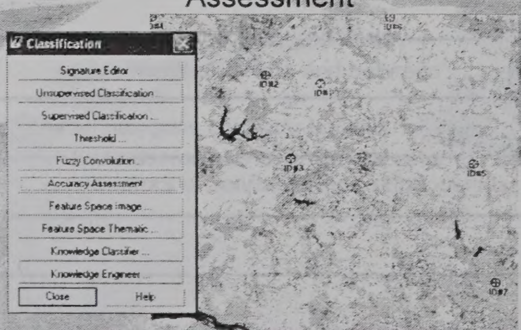
Error Matrix

Observed Data

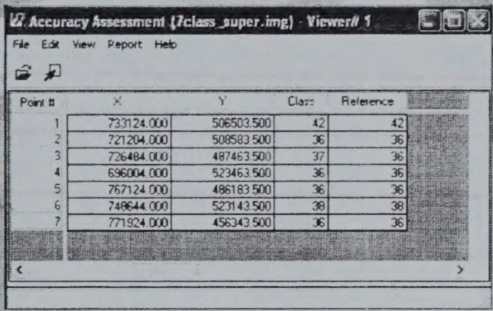
Modeled Class ~~Map Units~~

~~Point data~~	A	B	C	D
A	9	1	0	0
B	1	8	1	0
C	2	0	6	2
D	0	0	2	8

ERDAS Imagine Accuracy Assessment



ERDAS Imagine Accuracy Assessment Cell Array



Point #	X	Y	Class	Reference
1	733124.000	506503.500	42	42
2	721204.000	508583.500	36	36
3	726484.000	487463.500	37	36
4	696004.000	523463.500	36	36
5	767124.000	486183.500	36	36
6	748644.000	523143.500	38	38
7	771924.000	456343.500	36	36

Map Unit Accuracy (cont.)

- Statistical analysis
  - Helps determine significance of your determination of map unit accuracy
  - Helps you determine the amount of variability you have in your data

Summary

- Line work
- Adequate documentation
- Mapping accurately reflects soil-landscape relationships
- Evaluation should always focus on meeting customer needs

Exercise

- Using the Juniper Draw map created and ERDAS Imagine:
  - Calculate documentation required
  - Create an error matrix & determine map unit accuracy for the 3 classes
  - Discuss meaning and value of accuracy assessment

Evaluation Exercise

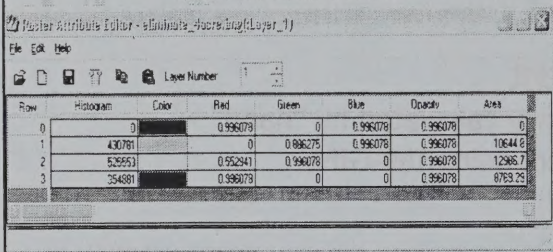
- Juniper Draw 7.5 min quad
  - Total area clumped into 3 classes
- MOU Data Requirements - IMAGINE
  - Calculate area in each class
  - Calculate number required:
    - Pedons
    - Transects
    - Observations
- Accuracy Assessment
  - Error matrix, accuracy calculated by "hand"
  - Accuracy assessment using IMAGINE

Evaluation: MOU Data Requirements

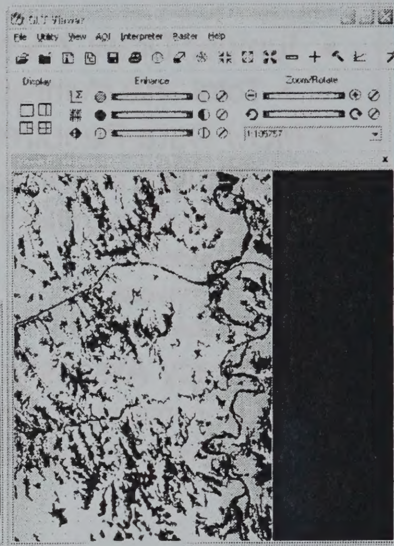
- Pedons
  - 3 pedons/component
  - 1 pedon/3000 acres
  - Maximum = 10 pedons
- Transects
  - 2 transects/map unit
  - 1 transect/5000 acres
- Observations
  - 1 observation/150 acres

Evaluation: Calculate Area in Each Class

- Start IMAGINE
- Select GLT Viewer
  - Open File eliminate_4ac.img
  - Raster
    - Attributes
      - Edit
        - Add Area Column

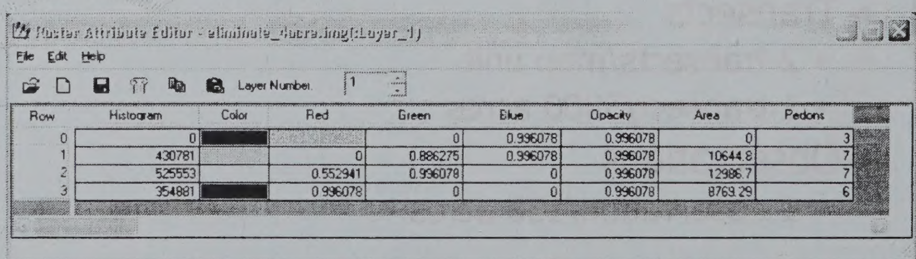


Row	Histogram	Color	Red	Green	Blue	Opacity	Area
0	0		0.996078	0	0.996078	0.996078	0
1	430781		0	0.886275	0.996078	0.996078	10644.8
2	525553		0.552941	0.996078	0	0.996078	12986.7
3	354881		0.996078	0	0	0.996078	8769.29



Evaluation: Pedons Required

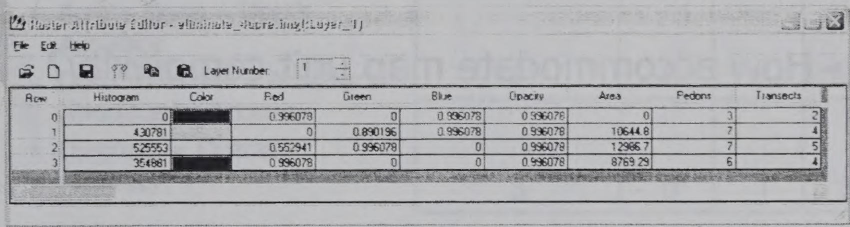
- Go to Raster Attribute Editor Table
  - Edit
    - Column Properties
      - Select New
      - Title = Pedons
      - Format = 0
      - Formula, Select MORE, enter
        - 3 + ($"Area"/3000), OK
      - Units (leave blank), OK



Row	Histogram	Color	Red	Green	Blue	Opacity	Area	Pedons
0	0			0	0.996078	0.996078	0	3
1	430781		0	0.886275	0.996078	0.996078	10644.8	7
2	525553		0.552941	0.996078	0	0.996078	12986.7	7
3	354881		0.996078	0	0	0.996078	8769.29	6

Evaluation: Transects Required

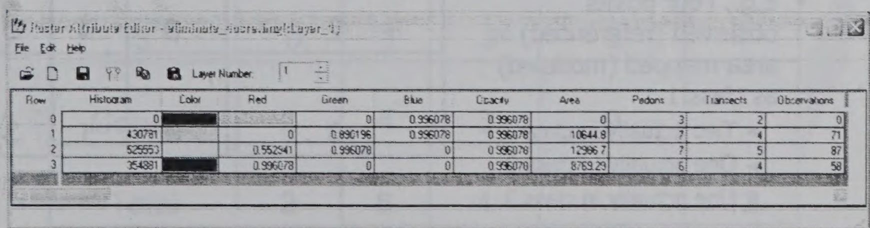
- Go to Raster Attribute Editor Table
  - Edit
    - Column Properties
      - Select New
      - Title = Transects
      - Format = 0
      - Formula = 2 + ($"Area"/5000)
      - Units (leave blank)
      - OK



Row	Histogram	Color	Red	Green	Blue	Opacity	Area	Pedons	Transects
0	0		0.996078	0	0.996078	0.996078	0	3	2
1	430781		0	0.890196	0.996078	0.996078	10644.8	7	4
2	525553		0.552941	0.996078	0	0.996078	12986.7	7	5
3	354881		0.996078	0	0	0.996078	8769.29	6	4

Evaluation: Observations Required

- Go to Raster Attribute Table
  - Edit
    - Column Properties
      - Select New
      - Title = Observations
      - Format = 0
      - Formula = $"Area"/150
      - Units (leave blank)
      - OK



Row	Histogram	Color	Red	Green	Blue	Opacity	Area	Pedons	Transects	Observations
0	0		[illegible]	0	0.996078	0.996078	0	3	2	0
1	430781		0	0.890196	0.996078	0.996078	10644.8	7	4	71
2	525553		0.552941	0.996078	0	0.996078	12986.7	7	5	87
3	354881		0.996078	0	0	0.996078	8769.29	6	4	58

Evaluation Discussion

- How use information?
  - Map unit area
  - Pedons required per map unit
  - Transects required per map unit
  - Observations required per map unit

- How accommodate map unit complexity?

Evaluation: Accuracy Assessment – Error Matrix

- Assess the accuracy of the classification
  - Prepare Error Matrix
  - 12 Observations, 4 in each of 3 classes
    - Modeled class (map)
    - Observed class (field)
  - E.g., Four points observed (referenced) in area mapped (modeled) as class 1
    - Two actually in class 1
    - One actually in class 2
    - One actually in class 3

	Observed Class		
Modeled Class	1	2	3
1	2	1	1
2	0	4	0
3	0	1	3

Evaluation: Accuracy Assessment – Error Matrix

- Sum number of correct and total observations
  - Across Rows
  - Down Columns
  - Diagonal
- Calculate % correct
  - Across Rows = User's Accuracy
  - Down Columns = Modeler's (Producer's) Accuracy
  - Diagonal = Overall Accuracy

	Observed Class		
Modeled Class	1	2	3
1	2	1	1
2	0	4	0
3	0	1	3

Evaluation: Accuracy Assessment – Error Matrix

	Observed Class				
Modeled Class	1	2	3	Correct	Total
1	2	1	1	2	4
2	0	4	0	4	4
3	0	1	3	3	4
Correct	2	4	3	9	
Total	2	6	4		12

Evaluation:
Accuracy Assessment – Error Matrix

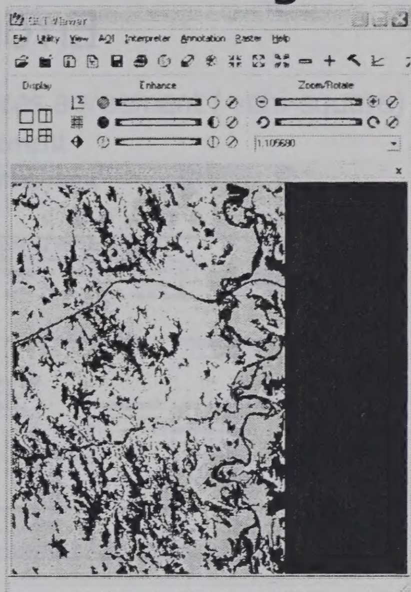
	Observed Class					
Modeled Class	1	2	3	Correct	Total	User's Accuracy
1	2	1	1	2	4	2/4 50%
2	0	4	0	4	4	4/4 100%
3	0	1	3	3	4	3/4 75%
Correct	2	4	3	9		
Total	2	6	4		12	
Modeler's Accuracy	2/2 100%	4/6 67%	3/4 75%			Overall Accuracy 9/12 75%

Evaluation:
Accuracy Assessment – Error Matrix

- User's Accuracy
  - Classes modeled as 1, 50% accurately classified
  - Classes modeled as 2, 100% accurately classified
  - Classes modeled as 3, 75% accurately classified
- Modeler's (Producer's) Accuracy
  - Classes observed as 1, 100% accurately modeled
  - Classes observed as 2, 67% accurately modeled
  - Classes observed as 3, 75% accurately modeled
- Overall Accuracy
  - 9 Correct/12 Total = 75% accuracy overall

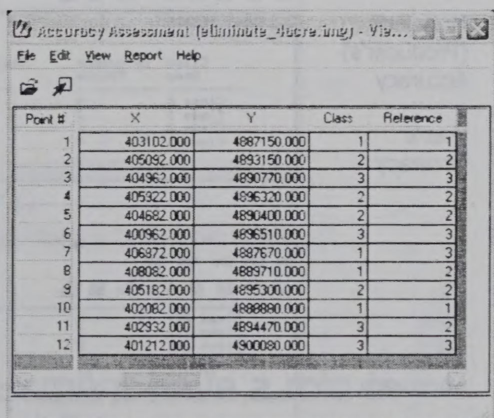
Accuracy Assessment - Imagine

- Go to IMAGINE
- GLT Viewer
  - Open file eliminate_4acre_12points
  - See overlay of 12 points (if not there, View, Arrange Layers to put points on top)



Accuracy Assessment - Imagine

- Select Classifier
  - Select Accuracy Assessment
    - Open file eliminate_4acre_12points
    - Edit
      - Show Class Values
    - Report
      - Accuracy Report



Point #	X	Y	Class	Reference
1	403102.000	4887150.000	1	1
2	405092.000	4893150.000	2	2
3	404962.000	4890770.000	3	3
4	405322.000	4896320.000	2	2
5	404682.000	4890400.000	2	2
6	400962.000	4896510.000	3	3
7	406872.000	4887670.000	1	3
8	408082.000	4889710.000	1	2
9	405182.000	4895300.000	2	2
10	402082.000	4888880.000	1	1
11	402932.000	4894470.000	3	2
12	401212.000	4900080.000	3	3

Accuracy Assessment - IMAGINE
Error Matrix

Editor: ecoar003440, Dir: c:/docume~1/jlboett/locals~1/temp/

File Edit View Find Help

CLASSIFICATION ACCURACY ASSESSMENT REPORT

Image File : c:/program files/imagine 8.6/examples/billy_from_nephi/eliminate_4acre.img
User Name : jlboett
Date : Mon Feb 09 12:00:21 2004

ERROR MATRIX

	Reference Data			
Classified Data	Background	Class 1	Class 2	Class 3
Background	0	1	0	0
Class 1	0	1	1	1
Class 2	0	0	4	0
Class 3	0	0	1	3
Class 4	0	0	0	0

Accuracy Assessment - IMAGINE

Modeler's (Producer's) Accuracy

User's Accuracy

Overall Accuracy

Editor: ecoar002896, Dir: c:/docume~1/jlboett/locals~1/temp/

File Edit View Find Help

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Class 0	0	0	0	---	---
Class 1	2	4	2	100.00%	50.00%
Class 2	6	4	4	66.67%	100.00%
Class 3	4	4	3	75.00%	75.00%

Editor: ecoar002896, Dir: c:/docume~1/jlboett/locals~1/temp/

File Edit View Find Help

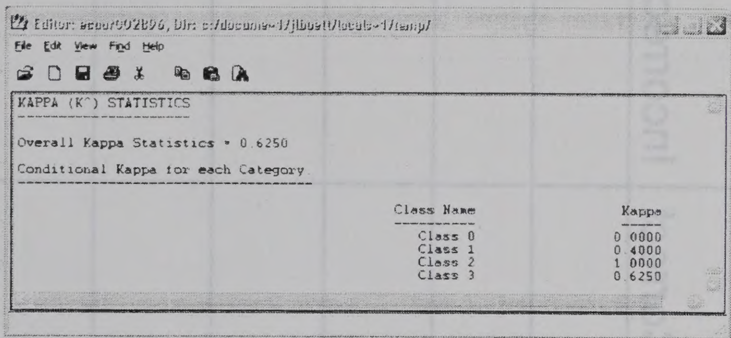
Class 253	0	0	0	---	---
Class 254	0	0	0	---	---
Class 255	0	0	0	---	---
Totals	12	12	9		

Overall Classification Accuracy = 75.00%

----- End of Accuracy Totals -----

Accuracy Assessment - Imagine

- ▶ Kappa Statistic (K^)
  - Multivariate analysis measures agreement (~chi-square)
    - ▶ K^ = 1.0-0.8 → Strong Agreement
    - ▶ K^ = 0.8-0.4 → Moderate Agreement
    - ▶ K^ < 0.4 → Poor Agreement



Accuracy Assessment Discussion

- ▶ How use?
  - Error matrix
  - Accuracy
    - ▶ User's
    - ▶ Modeler's (Producer's)
    - ▶ Overall
  - Kappa Statistic
- ▶ Does accuracy assessment have a role in future NCSS standards?

	Observed Class					
Modeled Class	1	2	3	Correct	Incorrect	User's Accuracy
1						
2						
3						
Correct						
Incorrect						
Modeler's Accuracy						Overall Accuracy

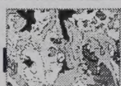
TEUI

TEUI Geospatial Toolkit

What is TEUI?

- TEUI is an integrated and ecological approach to mapping and classifying ecosystems.
- TEUI products include databases, maps, unit descriptions, and ecological interpretations
- TEUI stratifies the landscape into manageable units that provide baseline information in land management:
  - Burned Area Emergency Rehabilitation
  - Watershed Assessments
  - Forest Planning and Project-level analysis

TEUI Geospatial Tooll

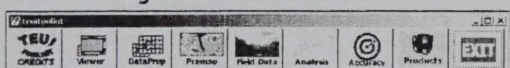


What is TEUI (cont.)?

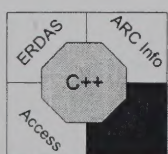
- Meets NCSS all standards.
- Plus additional requirements:
- Integrated plots
  - Vegetation
  - Geology

TEUI Geospatial Toolkit

Toolkit Design:



- Application is organized by TEUI business process
  - Phase I (FY2002)
    - Data Prep
    - Premap
    - Field Sample
  - Phase II (FY2003)
    - Landscape Analysis
    - Accuracy Assessment
    - Final Products



TEUI Geospatial Toolkit

Contact Information:

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John Lane:	Custer National Forest Soil Scientist Phone: (406)-657-6200 Email: jrlane@fs.fed.us
Jim Keys:	Ecosystem Management Coordination Team National Coordinator for Integrated Inventories Phone: (202)-205-1580 Email: jkeys01@fs.fed.us
Eric Winthers:	Ecosystem Management Coordination Team Terrestrial Ecological Unit Inventory Specialist Phone: (406)-522-2564 Email: ewinthers@fs.fed.us

TEUI Geospatial Toolkit

System Requirements:

- Hardware: $2,816
  - IBM Net Vista M41
    - 1.8GHz P4 processor
    - 1.5 GB RAM
    - 60 GB Hard Drive
- Software: $2,587 ($4,987)
  - Windows 2000
  - Microsoft Access
  - ArcGIS
  - ERDAS Imagine
    - New Basic ERDAS ($2,400)
    - New PC License $359
    - Virtual GIS $2,228

3D MAPPER

Advanced Technologies for Soil Survey: 3dMapper™

William R. Effland, Ph.D.
U.S. Department of Agriculture
Natural Resources Conservation Service

Acknowledgements

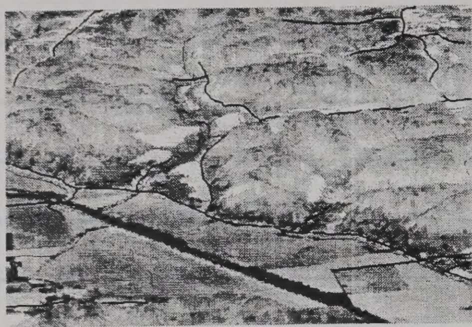
This presentation on the 3dMapper™ was partially developed from previous work completed by Drs. James Burt and A-Xing Zhu at the UWI-Madison Department of Geography.

Duane Simonson and Jesse Turk, WI NRCS soil scientists also provided some information for this presentation.

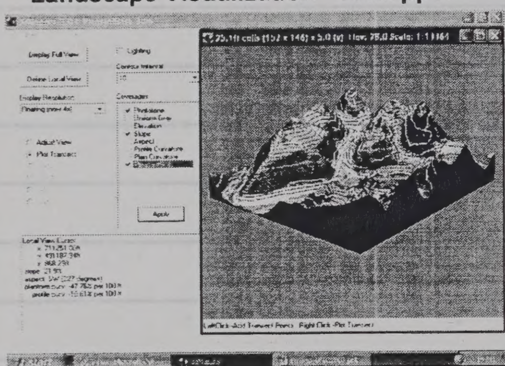
Soil Survey Technologies

- 3-Dimensional Visualization
  - ESRI ArcGIS 3D Analyst and ArcScene
  - Terrain Analytics 3dMapper™
  - Digital Elevation Models
  - Digital Orthophotography
- Geographic Information Systems (GIS)
- Soil-Land Inference Modeling (SoLIM)
- Remote Sensing

ArcScene of Upper Iowa River Valley



Landscape Visualization - 3dMapper™



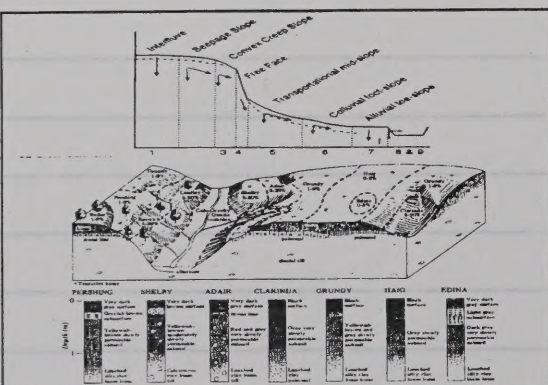
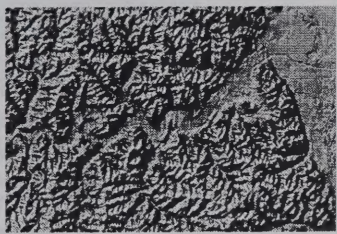


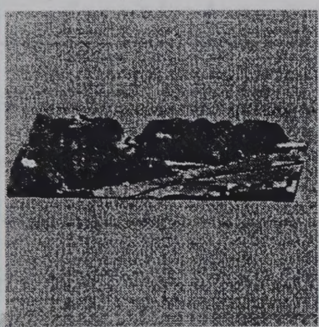
Figure 2.2 Relation of slope (%), vegetation, and parent material to soil series in southern Iowa. Upland soils have formed from loess (O-isotope stage 2 age), and valley side soils have formed either from reexposed older soils (paleosol) or from unweathered Kansan Till. *(Reprinted from Oschwald and others, 1965, Fig. 15.)*

Basic Products from DEMs

- Elevation
- Contours
- Slope
- Aspect
- Slope curvature
  - Planform
  - Profile

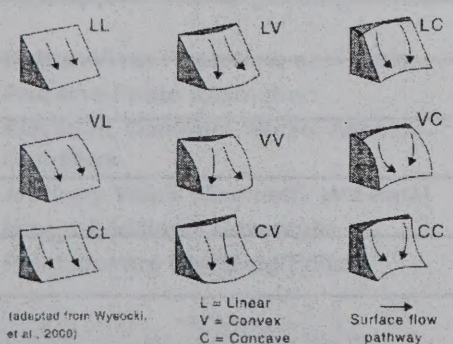


3dMapper™ - Basic Coverages



- Phototone
- Uniform Gray
- Elevation
- Slope
- Aspect
- Profile Curvature
- Planform Curvature

Slope Planform and Profile Curvature



Derivative Products from DEMs

- Ridgeline
- Watersheds
- Wetness index
- Stream power index
- Sediment transport factor
- Viewshed
- Local drain direction
- Upstream elements/ area/specific catchment area
- Stream length
- Stream channel
- Drainage network classification
- Catchment length

Geospatial Data Manipulation

- Point Coverages
- Line Coverages
- Polygon Coverages
  - Drawing
  - Editing
  - Saving
- Undoing Edits

Advantages of 3dMapper™

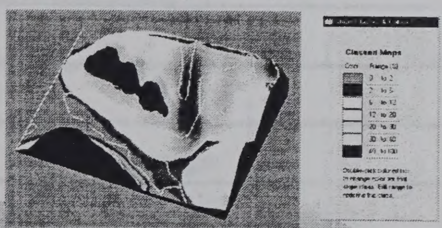
- Reduces some individual subjectivity for viewing in 3-D (stereoscope limitation)
- Allows multiple users to study 3-D landscape view at the same time
  - Aids training of new soil scientists
  - Enhances soil landscape model development
- Additional GIS layers viewed to help delineate soils or other natural resources
  - Raster slope map
  - Vectorized slope breaks
- Map products in a digital format (ortho-rectified) and readily available for GIS display and analysis

Disadvantages of 3dMapper™

- Base input data are very important
  - Digital elevation models (DEMs)
  - Digital orthophotography
- "Learning curve" for mapper
- Availability of other GIS layers?
- Computer hardware & software questions
  - High-end workstations (RAM)
  - Requires other GIS software for some pre-and post-processing steps

Current Use of 3dMapper™

- Knowledge Acquisition (SoLIM)
- Traditional Soil Survey
- Update Existing Survey



3dMapper™ Design Objectives

- Default View: Phototone on Terrain
- Preserve Photo Resolution
- Elevation, Contours, Slope, Aspect, Curvature
- Arbitrary Views (Geometry and Data)
- Import Additional Coverages
- Point and Arc Digitizing/Editing

Technical Issues for 3dMapper™

- Display Resolution
- Slope Neighborhood
- Line Drawing
- Inverse Projection

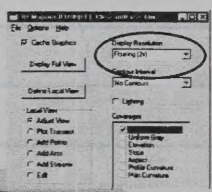
3dMapper™ Technical Issues
Display Resolution

Quarter Quad at 1m: ~5000 x 5000

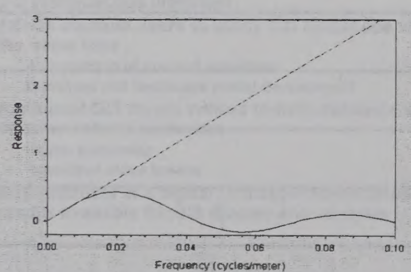
1km x 1km Local View: 10^6 polygons

Floating Resolution:

Given view extent, resample to achieve ~300 x 300 cells

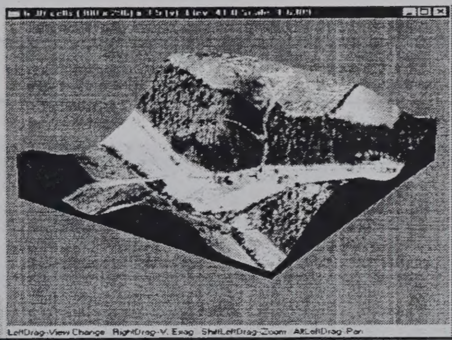


3dMapper™ Technical Issues
Slope Neighborhood



3dMapper™ Technical Issues

Line Drawing in 3-D



3dMapper™ Technical Issues

Inverse Projection

Given screen coordinates (i,j), find landscape coordinates (x,y,z)

a) Find cell containing (i,j) that is nearest camera

b) Poor man's rubber sheet

3dMapper™ Versions

- Free (NRCS, ver 2.11): http://solim.geography.wisc.edu
- Commercial (ver 3.05): http://www.TerrainAnalytics.com
  Features not in free version:
  - Polygon topology and editing
  - Shapefile import and export for points, arcs, polygons
  - Arc simplification (generalization) and smoothing (splining)
  - Partial arc move
  - Convert slope breaks to arcs
  - Cut and paste arcs between layers
  - Save local view as jpeg, gif or bmp; print local view
  - Save DEM-derived data (slope, curvatures, etc.)
  - Construct palette on raster input
  - Transparent slope classes
  - Undo function for editing layers
  - Automatic panning while digitizing
  - Hot-keys for shifting (panning) the local view

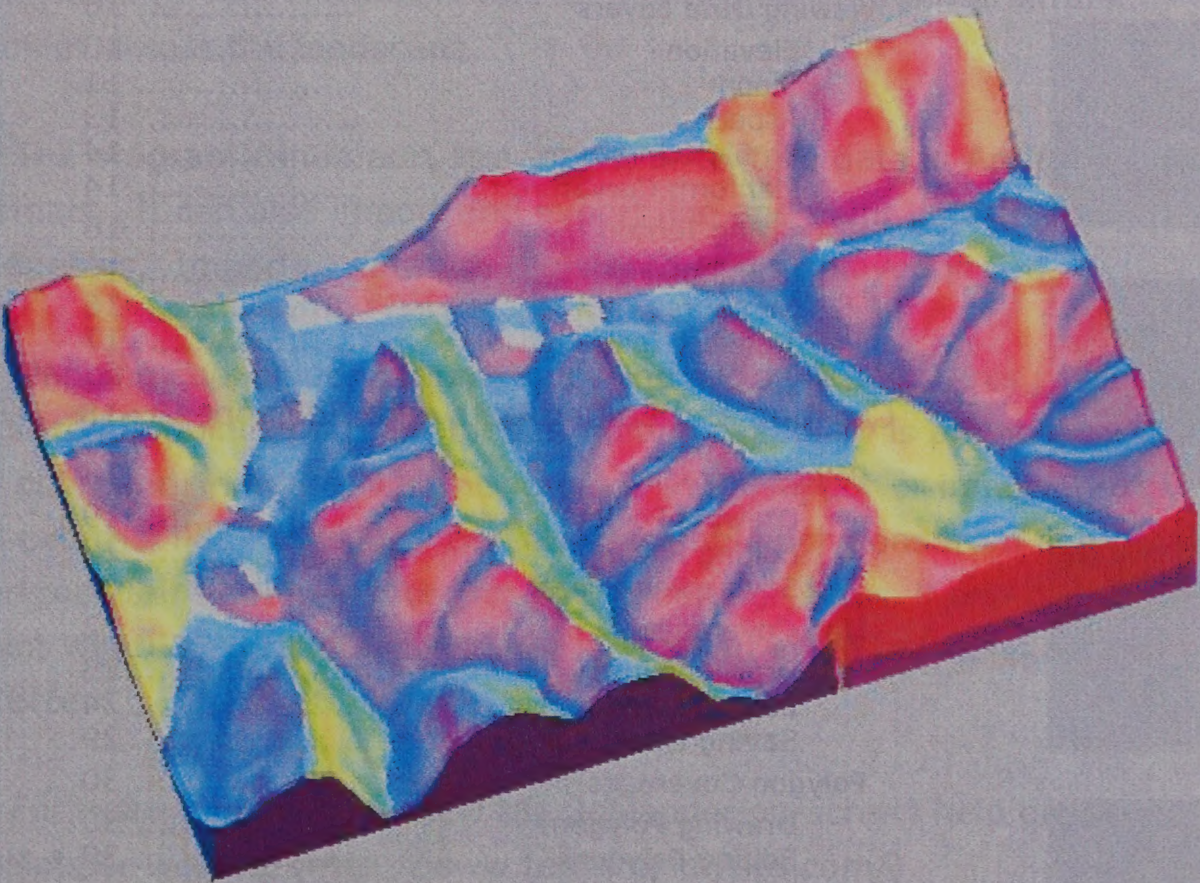
3dMapper™ V. 4 Enhancements

- Additional File Import Formats
- Other Terrain Variables
- Layer Transparencies, etc.
- Raster to Vector Conversion
- Polygon Editing w/ Attributes
- Stereo Viewing

Internet Sources

- http://soils.usda.gov
- http://solim.geography.wisc.edu/
- http://www.TerrainAnalytics.com

Introduction to 3dMapper



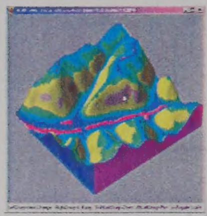
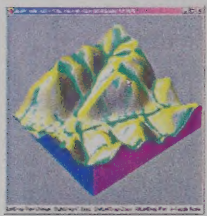
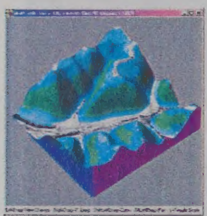
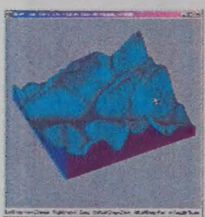
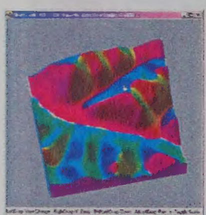
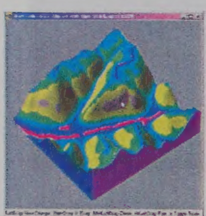
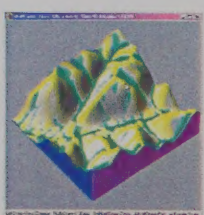








Table of Contents

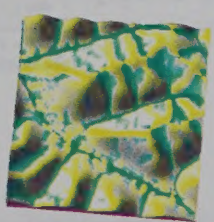
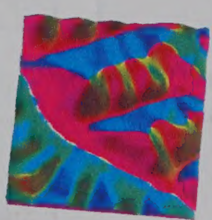
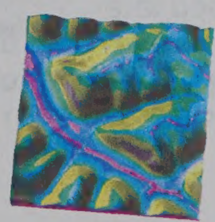
I. Introduction to 3dMapper

3dMapper is used for 3-dimensional landscape visualization and mapping. It has capabilities for rapidly viewing terrain from arbitrary positions, with variable veritcal exaggeration. It can display phototone, elevation, slope, aspect, and curvatures (alone or in combination) with optional synthetic lighting. Contour lines are available at a user-selected interval. A transect tool is provided for creating arbitrary profiles across the landscape.

The program can import line, point, or texture data in ArcInfo ascii formats. It can also import and export line and point data as ArcView shapefiles. Imported data are registered and displayed in 3-d.

Mapping capabilities include point and arc digitizing. Arcs can be digitized in point or stream mode. Editing capability is provided for all point and line data, whether created in 3dMapper or imported from an external file. 3dMapper can also assemble polygons from line data, and maintains polygon integrity during editing. Thus, if one moves a point where several polygons intersect, all attached polygons are affected.

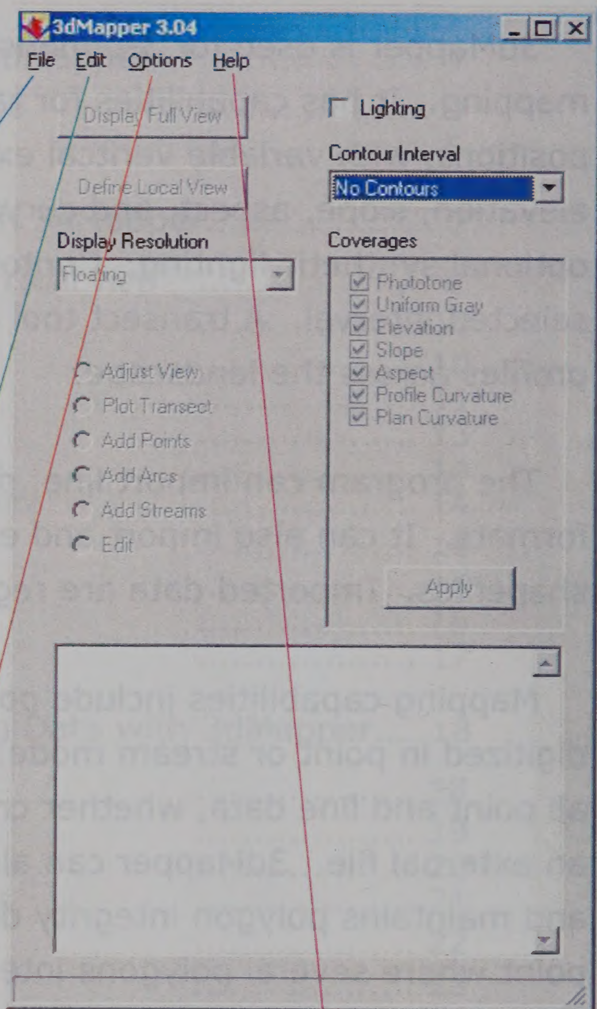
For more information, view the 3dMapper on-screen help or visit the 3dMapper website (http://www.terrainanalytics.com/).

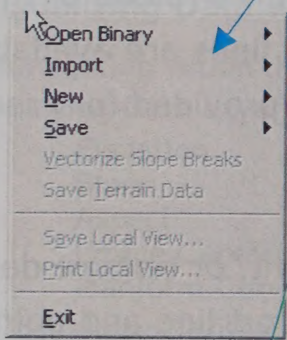
This information obtained from 3dMapper v3.04 on-screen help.

II. Getting Started with 3dMapper: The 3dMapper Interface

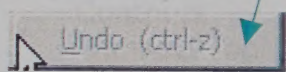
The first menu you see after starting 3dMapper is the main menu. All other 3dMapper functions will be initiated from this menu.



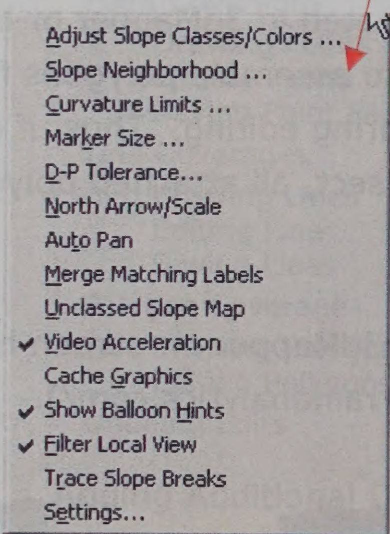
Choose File to open 3dMapper base files, import data, add data, create and save new arc or point files, among other things.



Choose Edit to Undo a previous action. (Only accessible during an editing session.)

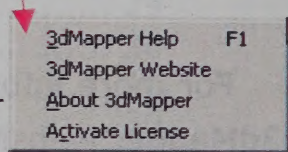


Choose Options to set various display and editing options for your 3dMapper session.



Adjust Slope Classes/Colors, Slope Neighborhood, Curvature Limits, Unclassed Slope Map, and Trace Slope Breaks will be discussed later. For more information about other 3dMapper options, see the 3dMapper help file accessible from the Help menu.

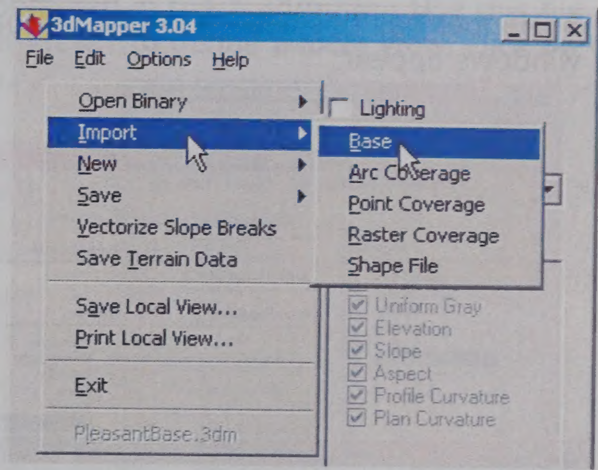
Choose Help to access 3dMapper Help, the 3dMapper Website, and to Activate your 3dMapper License (only needs to be done once.)



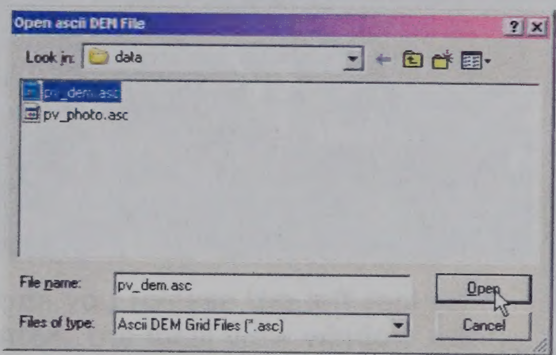
II. *Getting Started with 3dMapper:* Creating a Base File

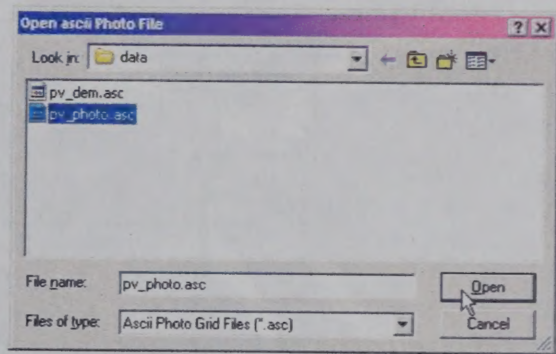
Before you can begin working in 3dMapper, you must create a base file. 3dMapper base files integrate an orthophotograph and a digital elevation model (DEM) to create a *.3dm file. Both the photo and DEM should be projected to an appropriate projection for the area of interest, clipped to the same extent, and converted to ascii files prior to importing into 3dMapper.

To import a base file once ascii files have been created, click:
File > Import > Base.

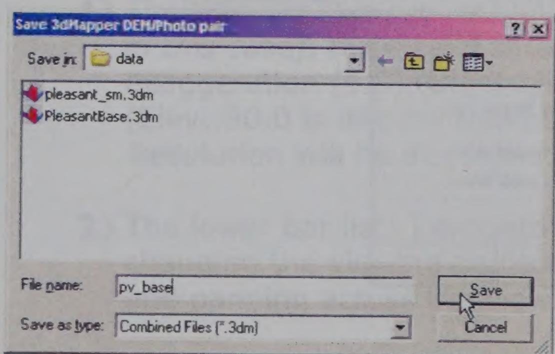


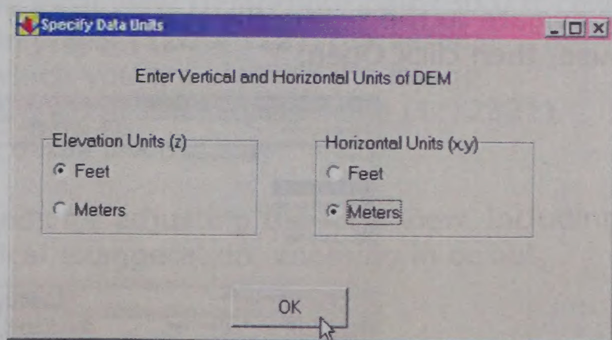
Then, in the Open ascii DEM File window, navigate to the directoy in which your data is stored, click on the dem ascii file, and click open. Next, in the Open ascii Photo File window, click on the photo ascii file and click open again.





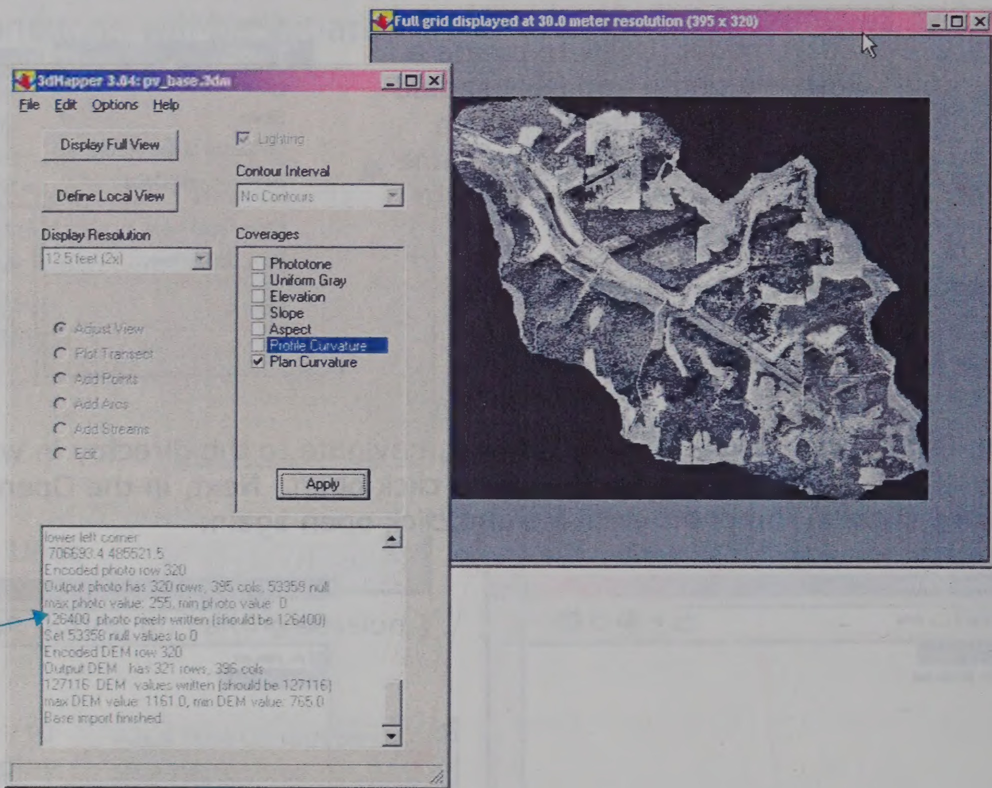
In the Save 3dMapperDEM/Photo Pair window, navigate to the directory in which you want to store your data, enter a name, and click save. The next window asks you to specify the units of the DEM. Most likely, the DEM will have vertical units of *feet* and horizontal units of *meters.* If you aren't sure, ask a GIS specialist. Click OK to continue importing the base file.





II. Getting Started with 3dMapper: Creating a Base File

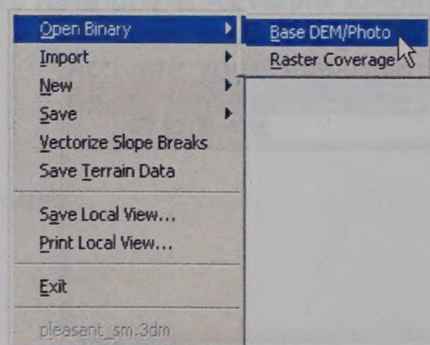
3dMapper has finsihed importing the base file when the main menu and Full Grid windows appear.



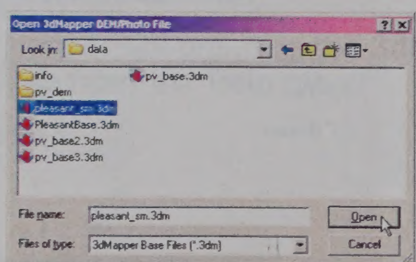
Note the base file information now contained in the main menu.

Now you're ready to begin working with 3dMapper!

Note: You only need to create a base file once per study area. To use an existing base file in 3dMapper, start 3dMapper, then on the main menu, click **File > Open Binary > Base DEM/Photo.**

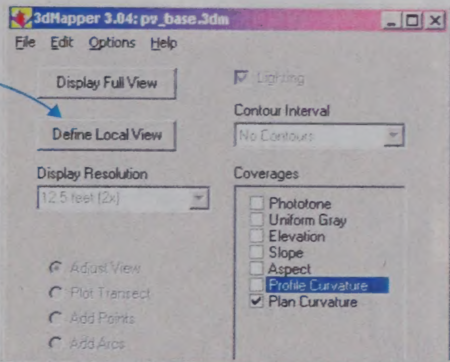


Navigate to the *.3dm file you want to use, then click Open.

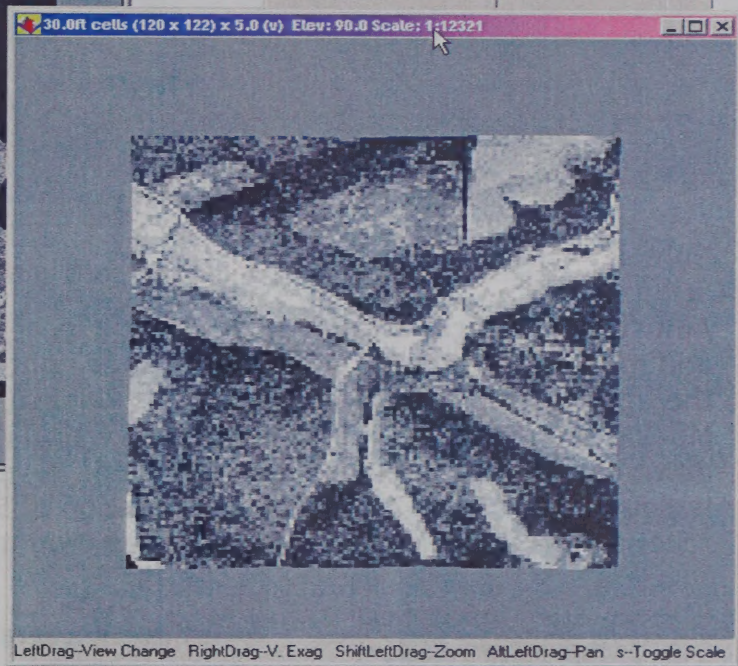


III. Visualizing Data with 3dMapper: *Navigating within the Local View*

The Full Grid window displays the entire area contained in the *.3dm file. Use this file to select a smaller area of interest called a Local View. To define a local view, click on the Define Local View Button on the main menu.



Then, left-click in the Full Grid window and drag a box around the area of interest.



When you release the left mouse button, the local view window will appear. To change the local view, click again on the Define Local View button and draw another box.

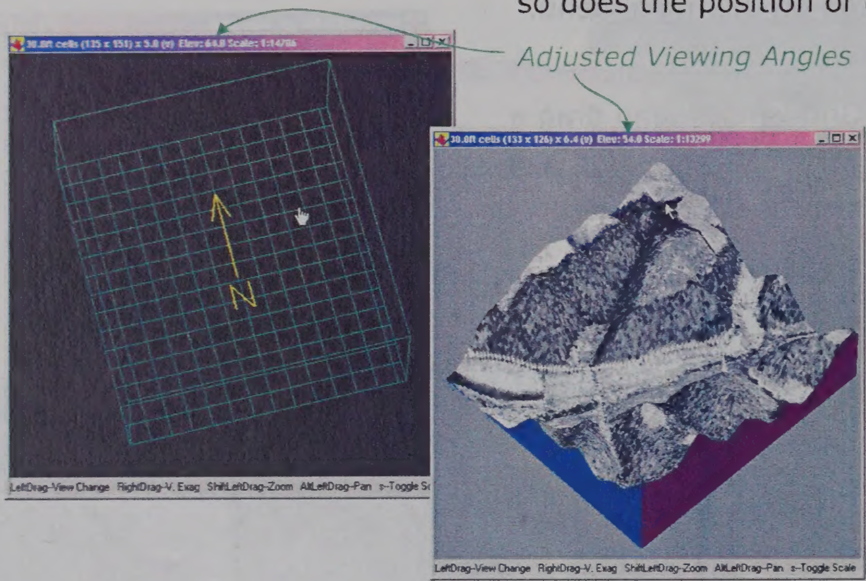
Things to note about the Local View window:

1) The title bar lists the resolution of the local view DEM/Photo pair (30.0 ft cells in this case), the size of the display in pixels (120 x 122), the vertical exaggeration (5.0), the angle from which you are viewing the image (Elev: 90.0 is directly overhead), and the current display scale (1:12321). Resolution will be discussed in more detail later.

2) The lower bar lists keyboard commands for adjusting the local view, including changing the viewing angle and vertical exaggeration, zooming in or out, and panning across the view.

III. *Visualizing Data with 3dMapper:* Navigating within the Local View

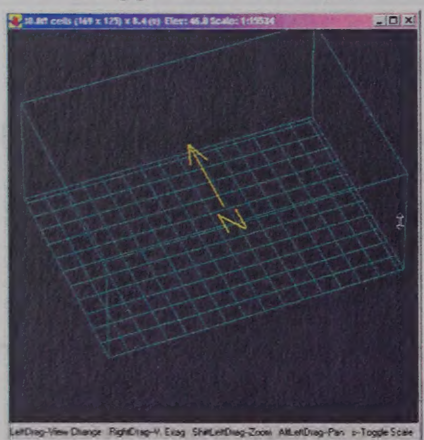
Adjust the **Viewing Angle** of the local view by left-clicking in the local view window and then simply moving the mouse. The local view window turns black, the terrain data is replaced by a green grid, and a north arrow is superimposed. As the mouse moves, so does the position of the grid. Release the mouse button to see the results.



Moving the mouse left to right changes the view azimuth while moving the mouse up and down changes the view elevation Elev = 90 means you're looking straight down at the landscape. Elev = 0 means you're looking sideways at the landscape.

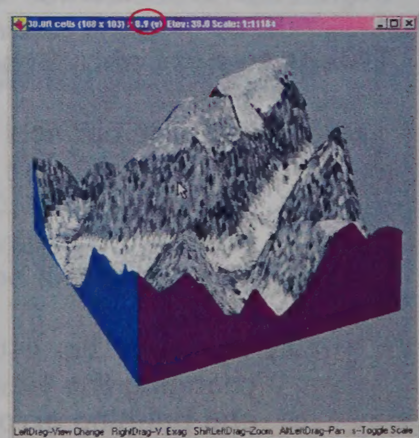
Adjust the **Vertical Exaggeration** of the local view by right-clicking in the local view and moving the mouse up or down. After right-clicking, the local view turns black and the image is replaced by a green grid. Release the mouse button to see the image again. Moving the mouse up will increase the vertical exaggeration while moving the mouse down decreases the vertical exaggeration. A vertical exaggeration of 0 means that the image appears flat. A vertical exaggeration of 5 (the default value) indicates that the relief appears 5 times more exaggerated than it actually is.

Adjusting the vertical exaggeration...8.4(v)



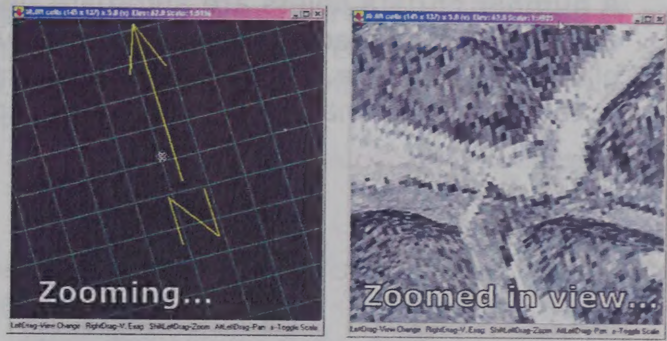
Vertical Exaggeration 1.0

Vertical Exaggeration 8.9

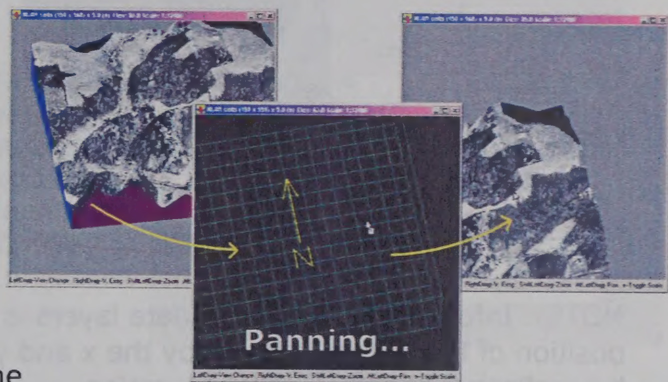


III. Visualizing Data with 3dMapper: *Navigating within the Local View*

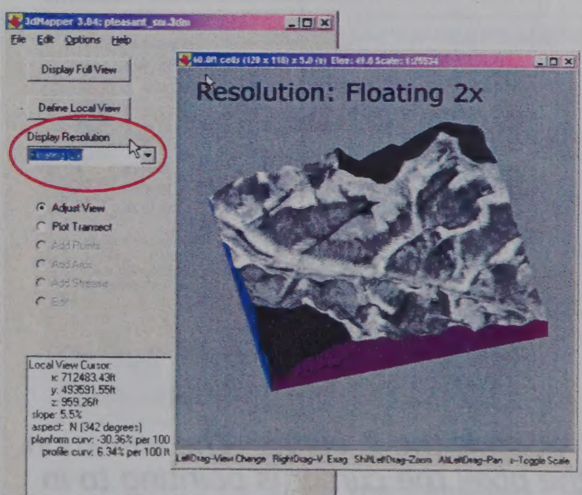
Zoom in and out within the local view by holding down the Shift key, then left-clicking in the local view. Move the mouse up to zoom in; move the mouse down to zoom out. Release the mouse-button to see the zoomed view.

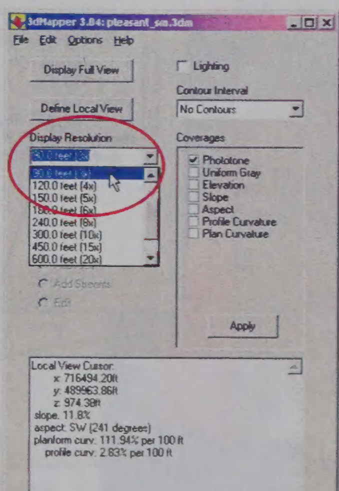


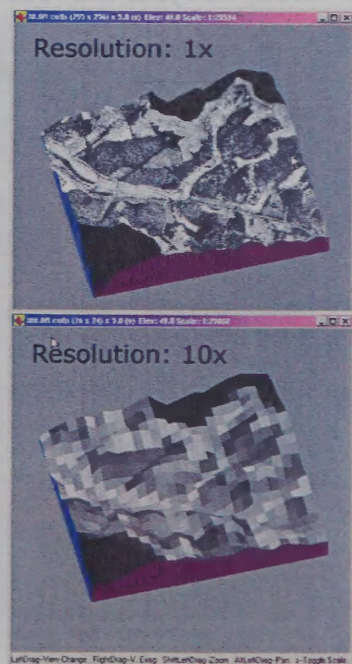
Pan across the local view by holding down the Alt and Shift keys and simultaneously left-clicking in the local view. Move the mouse to the left to pan left, move the mouse to the right to pan right.



Local View Resolution is a function the resolution of the original DEM/Photo pair, the size of the DEM/Photo pair (in pixels), and the size (in pixels) of the region selected for viewing. By default, small areas are drawn at high resolutions and larger areas are drawn at coarser resolutions. This is called "floating" resolution. It is also possible to manually designate the display resolution. Click on the triangle next to the Display Resolution box and choose a resolution from the drop down menu. Choosing a display resolution that's too high will result long draw times.



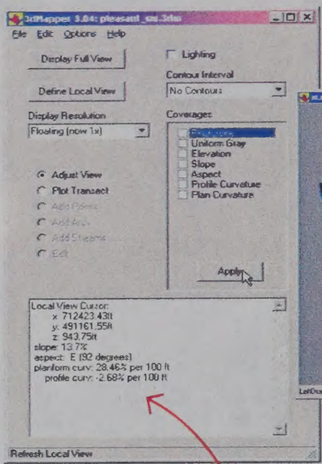




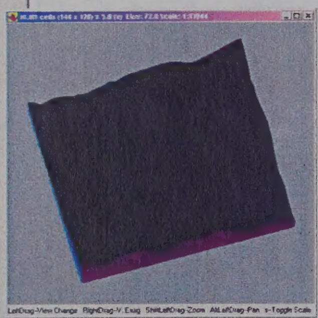
NOTE: Resolution 1x means the pixels in the local view are the same size as the pixels in the original image. Resolution 10x means the pixels displayed in the local view are 10 times the size of the pixels in the original image. These changes are done "on-the-fly" and do not affect the original image.

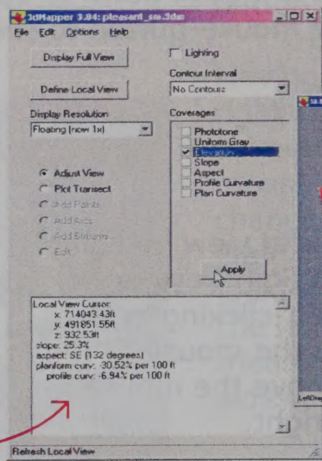
III. *Visualizing Data with 3dMapper:* *Viewing Data Layers*

A number of data layers are automatically generated from the DEM by 3dMapper when a base file is opened. These include: elevation, slope, aspect, profile curvature, and planform curvature. To **view** these layers (or additional layers added at a later time), or to turn off the imagery, click in the box to the left of the desired layer and then click apply.

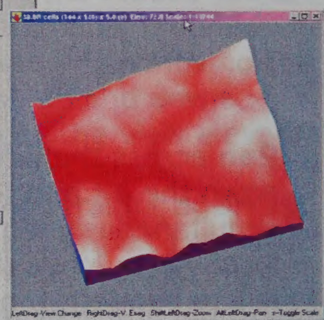


View after turning Phototone off...



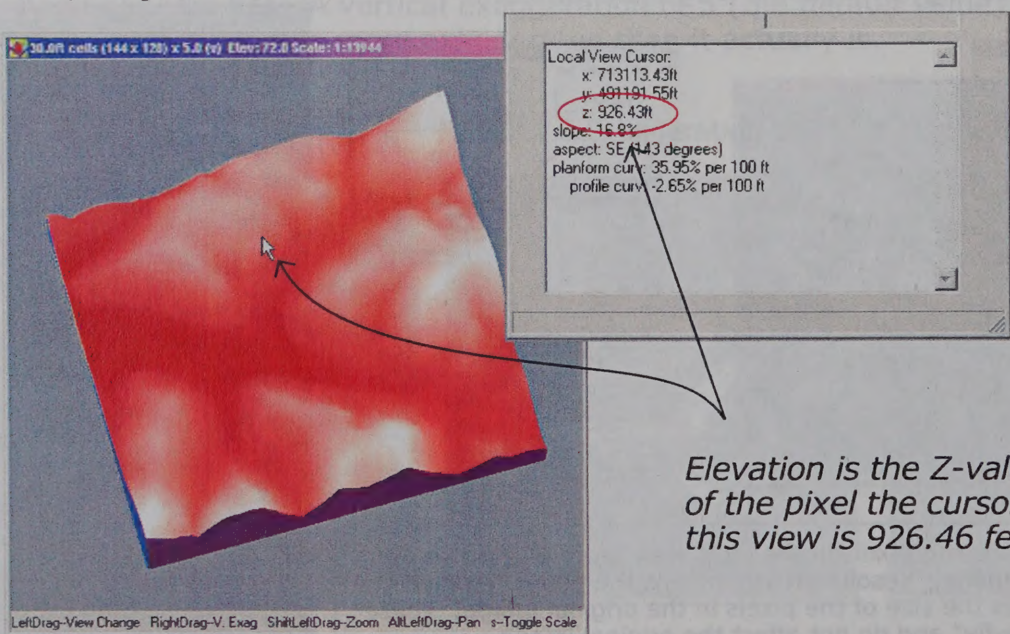


View after turning Elevation on...



NOTE: Information about the data layers is displayed in the 3dMapper main menu. The position of the cursor is given by the x and y coordinates. Other information displayed in this box reflects conditions at that location.

Elevation is depicted in either meters or feet, depending upon the original DEM. Lighter, less saturated colors indicate high elevations and darker, more saturated colors indicate low elevations. The elevation range reflects the change in elevation over the entire study area, not just the local view.

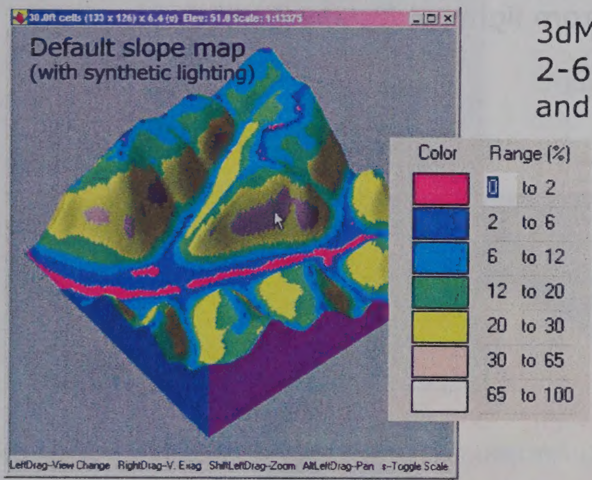


Elevation is the Z-value. The elevation of the pixel the cursor is pointing to in this view is 926.46 feet.

III. ***Visualizing Data with 3dMapper:*** *Viewing Data Layers*

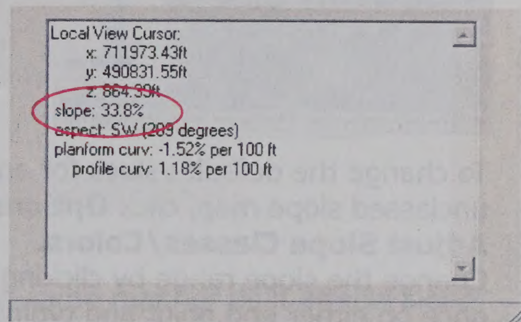
Slope gradient is expressed as a percentage and can be displayed as a classed map or an unclassed map. Classed slope maps use separate colors to depict predefined (either by 3dMapper or the user) slope classes while unclassed maps depict continuous change in gradient through gradual variation of one or two colors.

Classed Slope Maps:

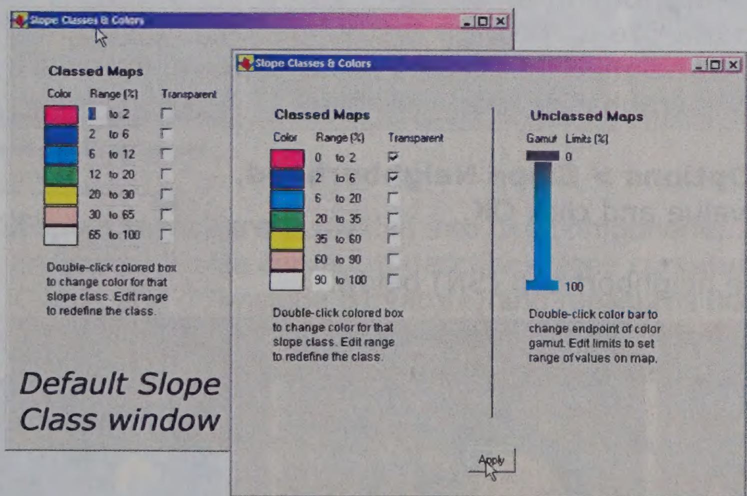


3dMapper's default slope classes are 0-2%, 2-6%, 6-12%, 12-20%, 20-30%, 30-65%, and 65-100%.

The slope gradient of the pixel under the cursor is 33.8%.

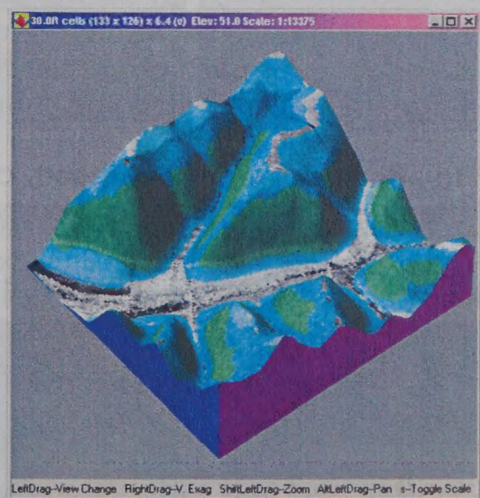


To change the default slope classes, or to render a particular slope class transparent, click **Options > Adjust Slope Classes/Colors** on the main menu. To change a slope class, click on a number in the range, then type the new value. Be sure to adjust the values of surrounding classes as well. To make a slope class transparent, check the box underneath the heading Transparent. After making the desired changes, click Apply.



Default Slope Class window

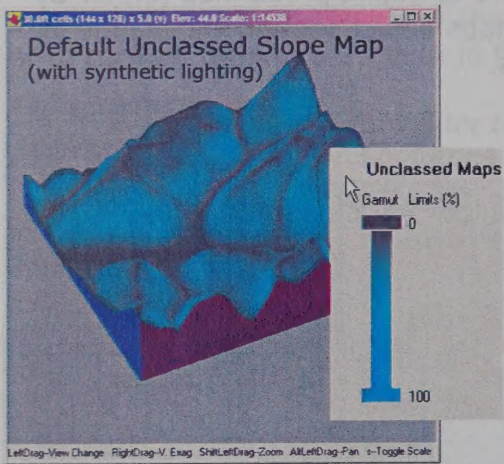
*Note the changes...*new slope classes 6-20%, 20-35%, 35-60%, 60-90%, and 90-100% and classes 0-2% and 2-6% have been made transparent.



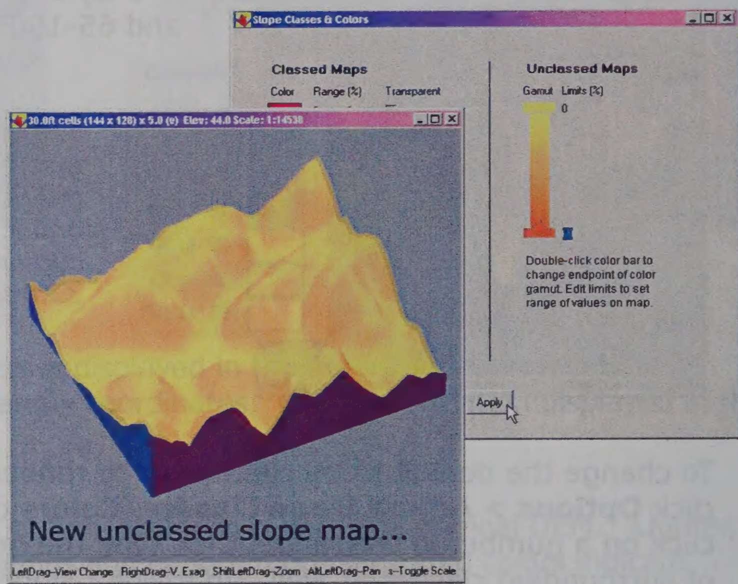
The slope map after changes have been applied...see default map above for a comparison.

III. *Visualizing Data with 3dMapper:* Viewing Data Layers

Unlassed Slope Maps:

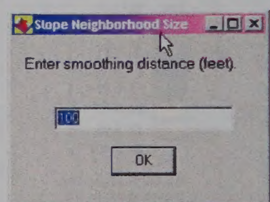


To create an unclassed slope map, click on **Options > Unclassed Slope Map**. This will replace the classed map with an unclassed map. The default unclassed map has a slope range of 0-100%. The default color scheme ranges from light to dark teal blue.



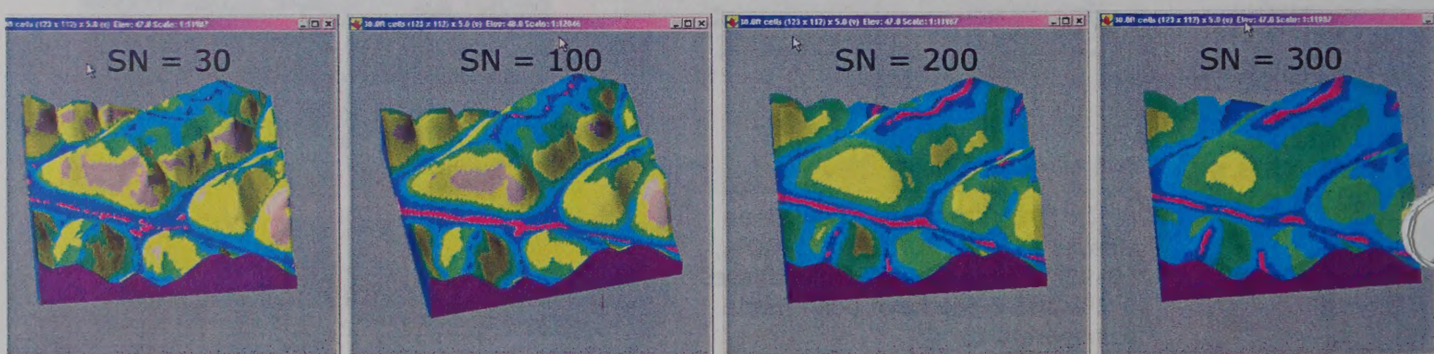
To change the default values for an unclassed slope map, click **Options > Adjust Slope Classes/Colors.** Change the slope range by clicking once on either end point and typing the new value. Change the color scheme by double-clicking on either end of the color ramp and choosing a new color. Click Apply to make the changes.

3dMapper lets you adjust the **Slope Neighborhood** for both classed and unclassed slope maps. Slope neighborhood refers to the size of the area that influences the slope calculation for each pixel. Larger slope neighborhoods generalize slope values over a large area. Small slope neighborhoods emphasize local variablitiy.



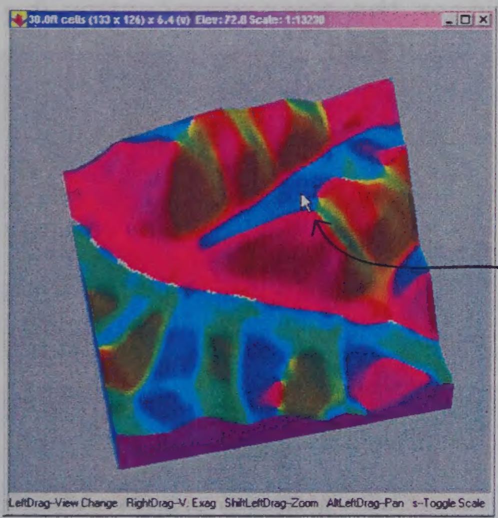
To adjust slope neighborhood, click **Options > Slope Neighborhood**, then type in the new neighborhood value and click OK.

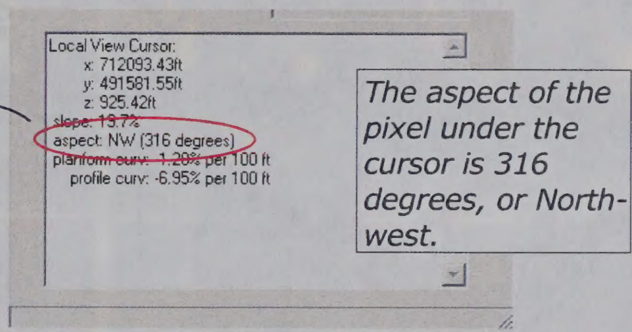
See the effects of changing the slope neighborhood (SN) below...



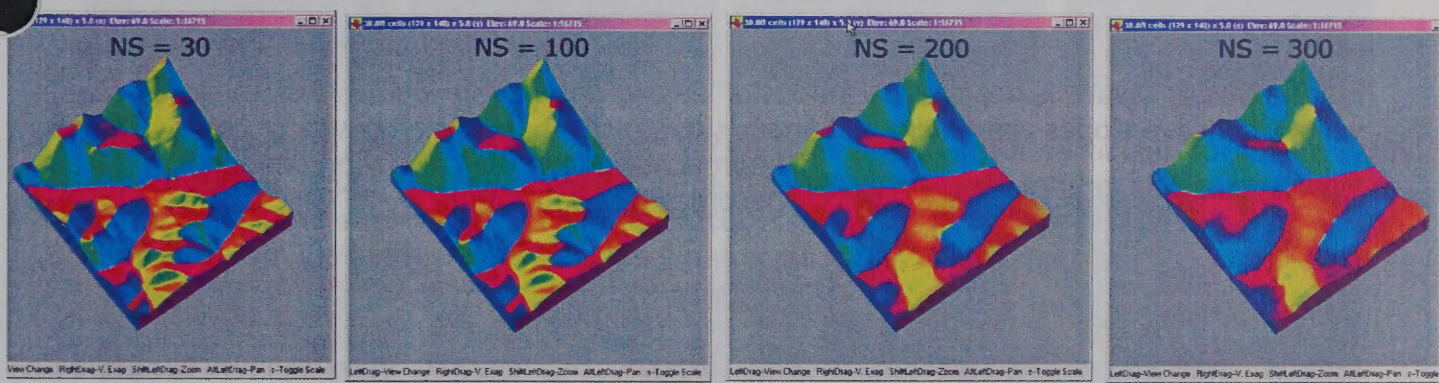
III. Visualizing Data with 3dMapper: Viewing Data Layers

Aspect is expressed in degrees measured clockwise from north. Areas with slopes less than 1% are considered flat. North aspects (0°) are colored blue and south aspects (180°) are colored red. Aspects between north and south have intermediate colors (i.e. southwest, west, and northwest aspects are typically blue to pink; southeast, east, and northeast aspects are typically yellow to green.)





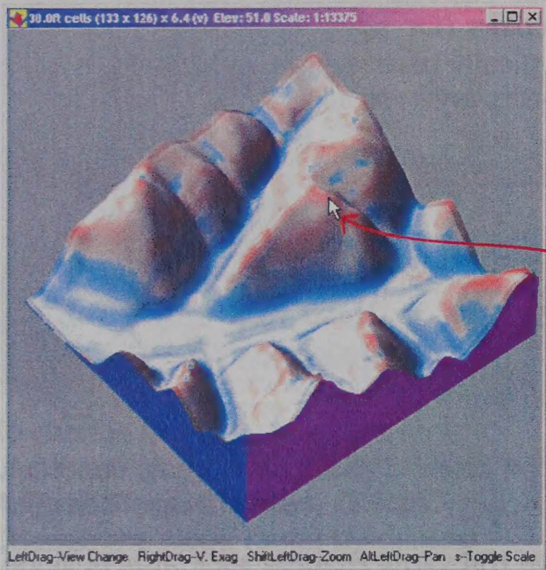
Neighborhood size affects the calculation of aspect in the same manner as it affects slope.

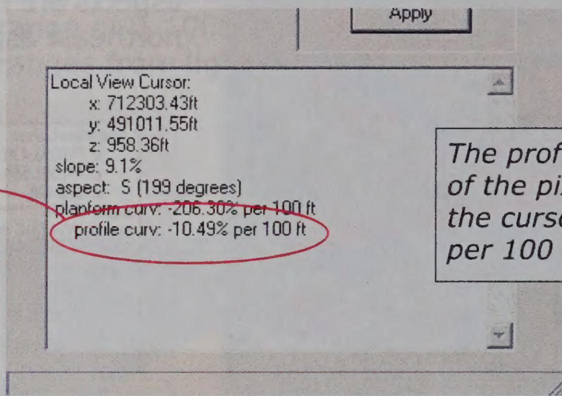


Slope Curvature is divided into two components...Profile Curvature and Planform curvature. Profile curvature describes slope curvature perpendicular to contour lines (i.e. upslope and downslope curvature) and measures how quickly the slope gradient is changing. Planform curvature describes slope curvature parallel to contour lines (i.e. across-slope curvature) and measures flow convergence and/or divergence.

3dMapper measures curvature in units of % per 100 feet (meters). Convex values are negative and concave values are positive Linear slopes have curvature values of approximately 0.

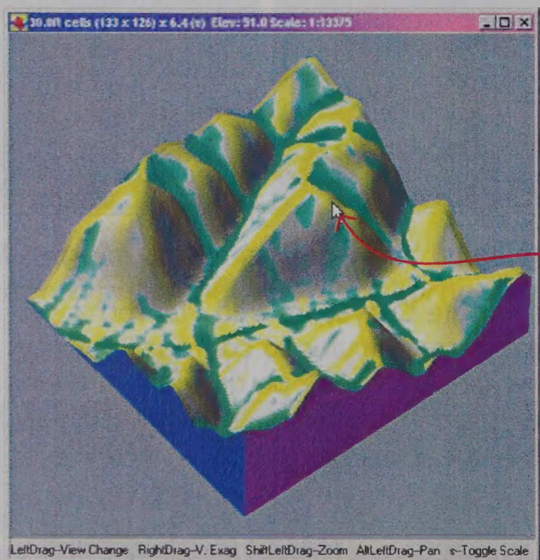
Profile Curvature is depicted in shades of red, blue, and white. Convex slopes are red, concave slopes are blue, and linear slopes are white. As a convex or concave slope approaches linear, the color representing it becomes less saturated.

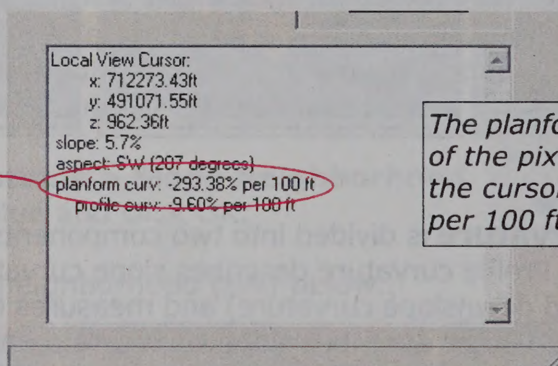




The profile curvature of the pixel under the cursor is -10.49% per 100 ft (convex).

Planform Curvature is depicted in shades of yellow, green, and white. Convex slopes are yellow, concave slopes are green, and linear slopes are white. As a convex or concave slope approaches linear, the color representing it becomes less saturated.



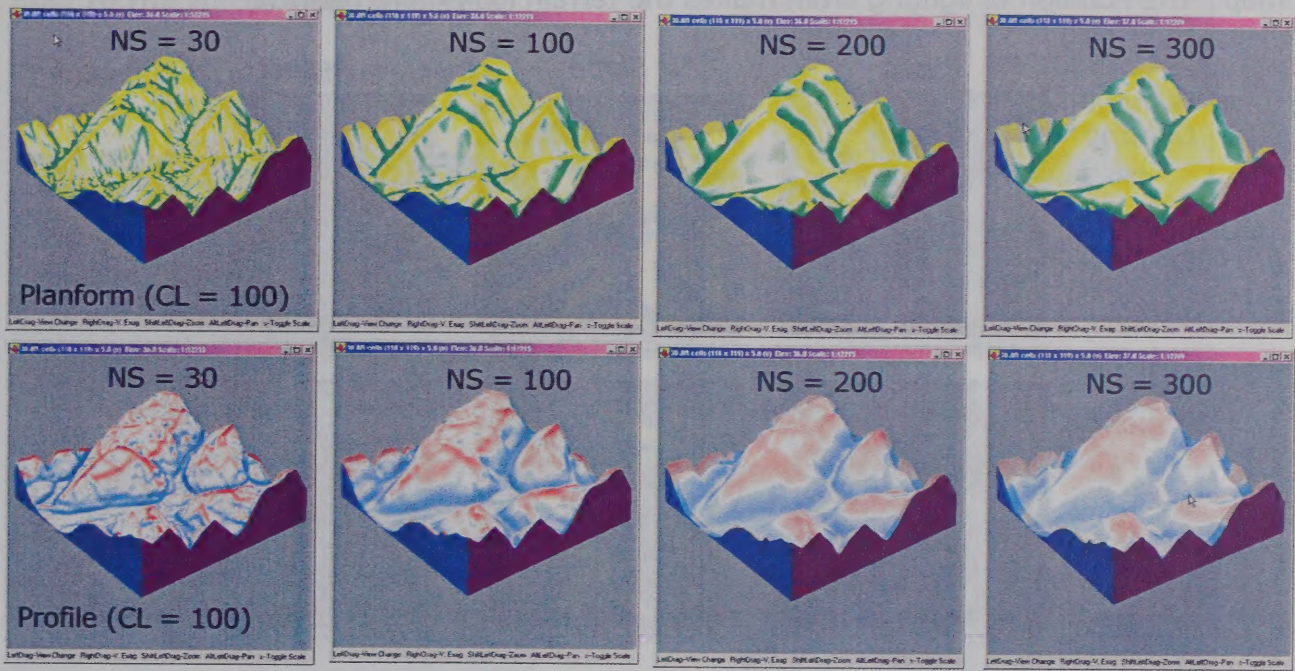


The planform curvature of the pixel under the cursor is -293.38% per 100 ft (convex).

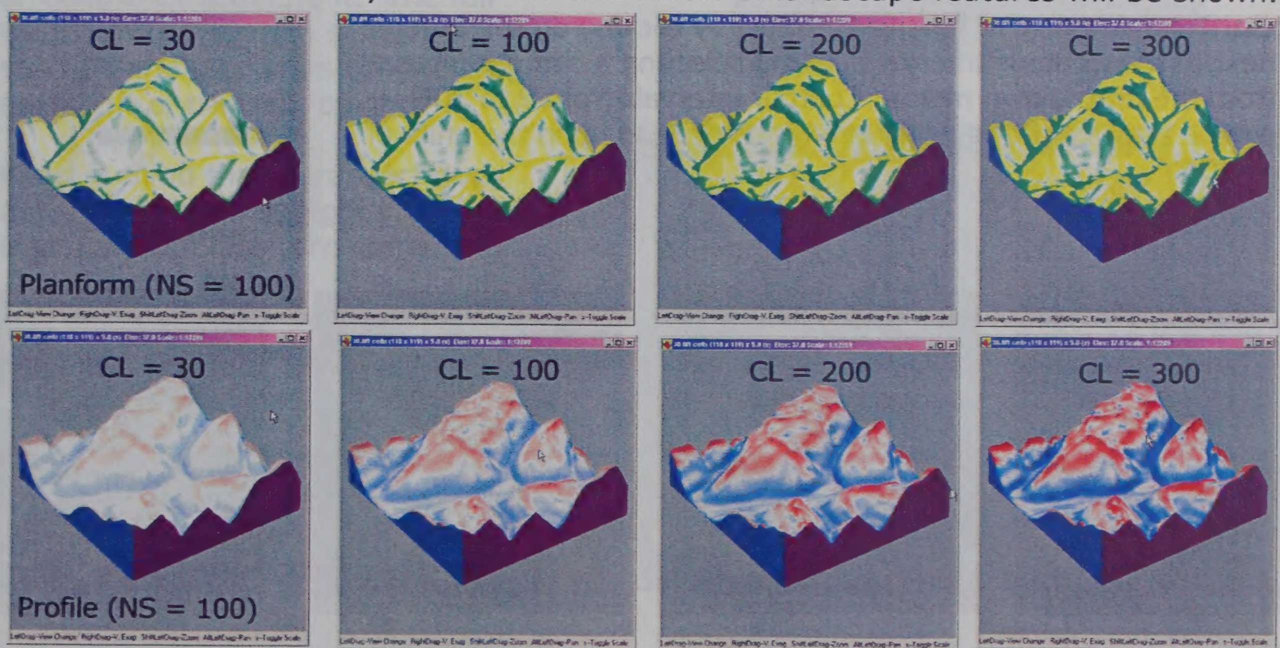
III. Visualizing Data with 3dMapper: Viewing Data Layers

Neighborhood size (NS) and curvature limits (CL) both affect the calculation of planform and profile curvature. NS and CL can be adjusted by clicking Options > NS or Options > CL.

Larger neighborhood sizes result in more generalized depictions of slope geometry. Smaller neighborhood sizes capture local variations in slope geometry.



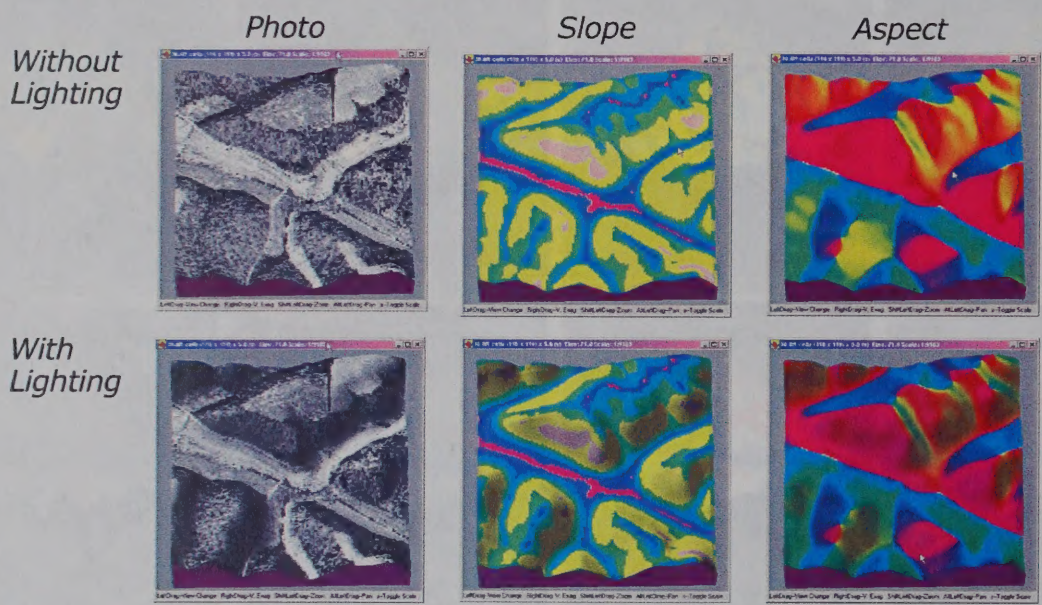
Curvature Limits determine what color will be associated with a particular curvature value. All curvature values (or the absolute value thereof) greater than the curvature limit are displayed in the same color. As small features tend to have large curvature values, the curvature limit effectively determines what scale of landscape features will be shown.



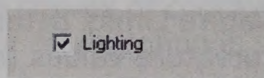
III. Visualizing Data with 3dMapper: Visualizing Terrain

3dMapper provides a number of methods for visualzing terrain in the local view, including the addition of synthetic lighting, the ability to add contour lines, and a transect tool.

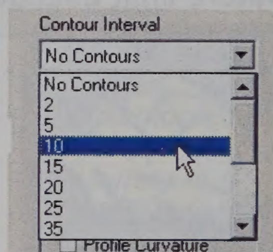
Adding **Lighting** to the local view is the equivalent of adding a hillshade or shaded-relief map. The addition of lighting often makes the terrain look more realistic.

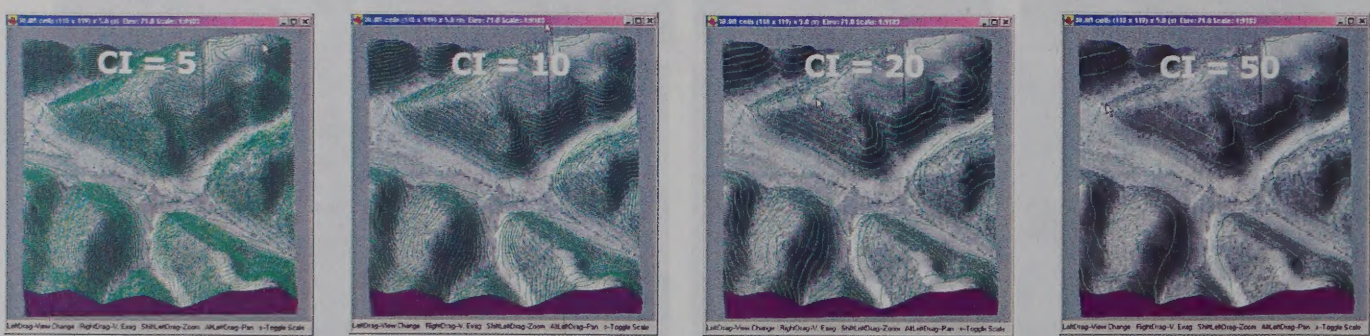


To add lighting to the local view, check the box next to Lighting on the main menu.



Contour Lines can be added simply by clicking on the triangle next to the Contour Interval box and selecting a contour interval from the drop down menu. Contour intervals from 2 to 300 can be applied. Units (meters or feet) depend upon the units of the DEM.

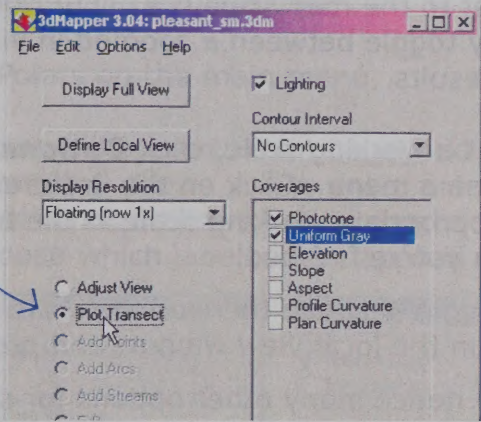




III. *Visualizing Data with 3dMapper:* Visualizing Terrain

The **Transect Tool** enables the user to plot a cross-sectional profile along an arbitrary line.

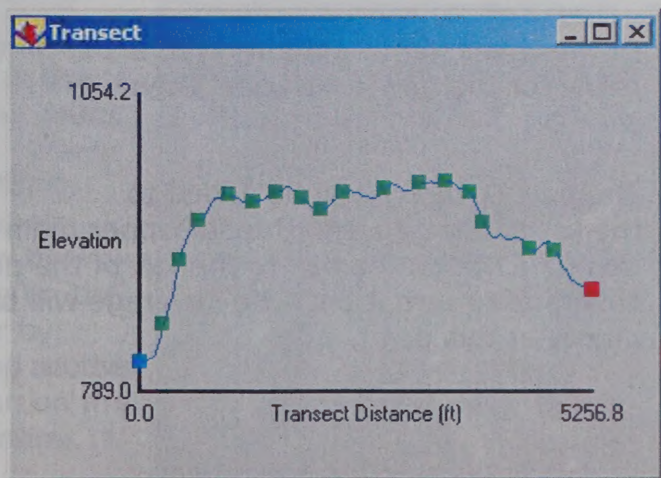
To create a transect, first click on the button next to the words *Plot Transect*.



Then, left click in the local view at the start of the transect.

Keep clicking to add additional points to the transect. When the end of the transect has been reached, right-click or double-click to end it. The full transect consists of a series of straight-line segments connecting each pair of transect points.

Keep in mind that a transect does not have to be a straight line... transects can also turn corners.



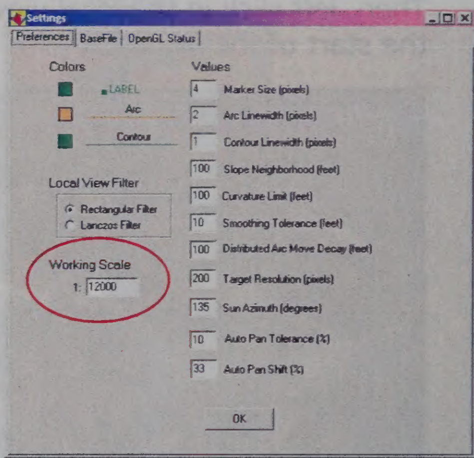
A profile of the transect path is generated as soon as the transect is ended.

Note: Remeber to click *Adjust View* on the Main Menu before attempting to adjust the position of the local view. Otherwise, you'll add another transect.

IV. Creating and Editing Data with 3dMapper

3dMapper has capabilities for creating and editing point, line, and polygon layers. Before you start editing, be sure to set a **Working Scale**. The working scale should be set to the map scale (i.e. 1:12,000 or 1:24,000). After setting the scale, you can easily toggle between a zoomed in view for editing and the working scale for viewing the results.

To set a working scale, click **Options > Settings** on the main menu. Click on the Preferences tab, then type an appropriate working scale in the box. Click OK when you're finished.

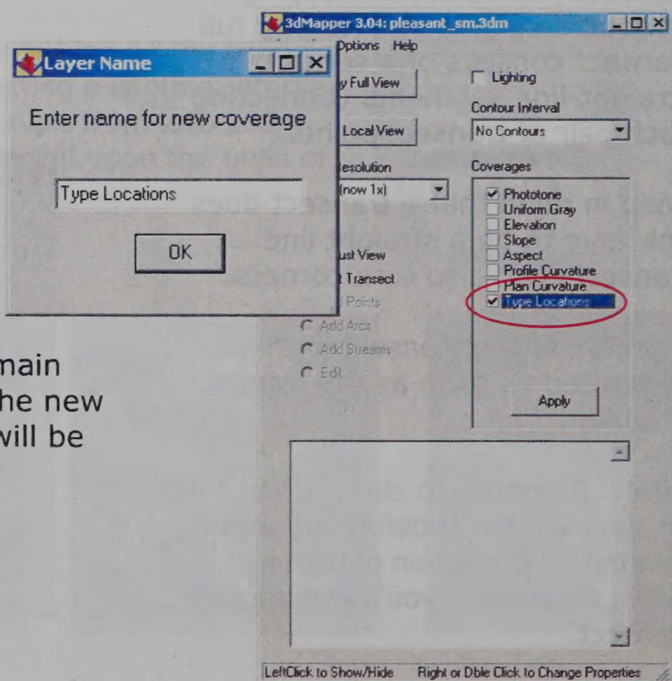


To toggle between the working scale and another scale, click in the local view window and press the 's' key.

You'll notice many other options for setting up a 3dMapper session in the Settings Window. To change a value, just type a new value. To change a color, double-click on the color and pick a new color. However, you may want to write down the default settings as changes to this menu are written to the initialization file.

Point Coverages contain a pair of coordinates marking the location of a particular feature and a label for that feature. Use points to mark the locations of soil pits or other observations.

To create a point coverage, click **File > New > Point Coverage** on the main menu.

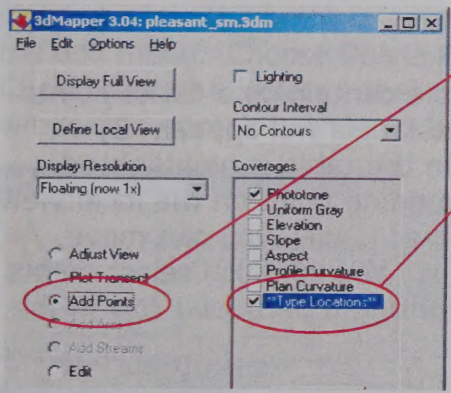


In the Layer Name window, type a name for the new coverage. Then click OK.

The new coverage will be added to the list of coverages in the 3dMapper main menu. Click on the box to the left of the new coverage to turn it on. The coverage will be empty at this point.

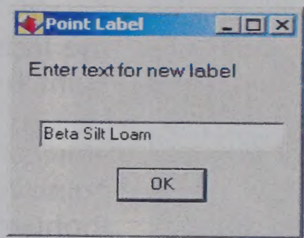
IV. *Creating and Editing Data with 3dMapper:* Points

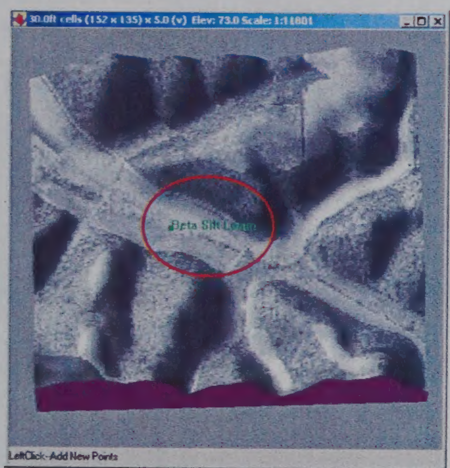
Before you can begin adding data to the new coverage, you must mark the coverage for editing. To do this, right-click on the new coverage, then click Mark for Additions or Edits. Notice that the coverage name is now surrounded by asterices.



Next, click Add Points on the main menu.

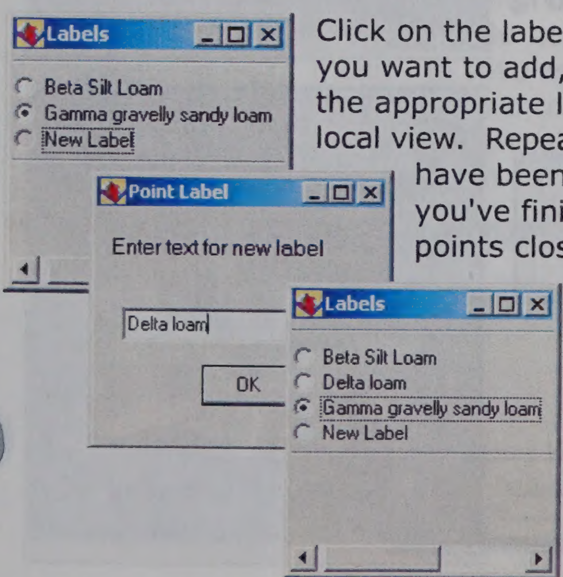
Two small windows will appear: Point Label and Labels. The Point Label window allows you to enter a name for a point. The Labels window allows you to create more labels and to choose which label will be applied to a given point.



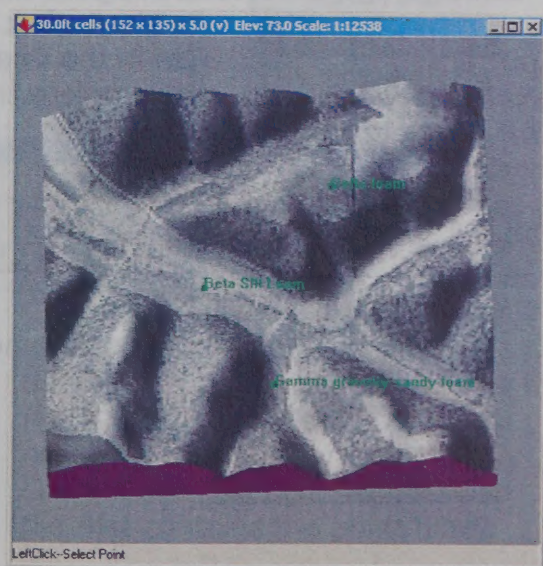


Once you've created a label, left-click in the local view on the location where you want to place the point. 3dMapper will add a point and label it. If you don't like the location of the point, click Edit > Undo and try again.

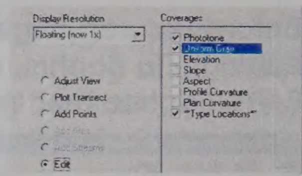
To add another point with the same label, click again in the local view. To add another point with a different label, click on New Label in the Labels window, then type another name in the Point Label window.



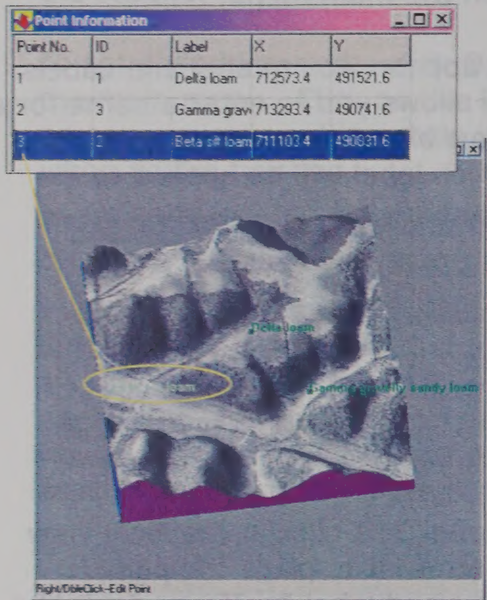
Click on the label of the point you want to add, then click on the appropriate location in the local view. Repeat until all points have been added. When you've finished adding points close the labels window by clicking on the [x], or by selecting another function on the main menu.



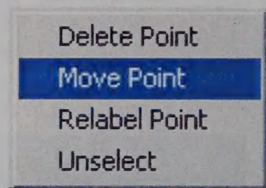
IV. *Creating and Editing Data with 3dMapper:* Points



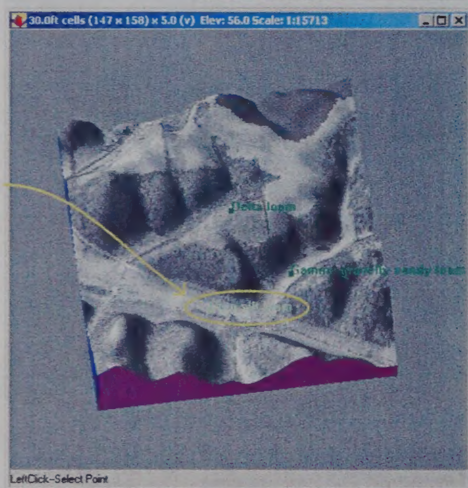
Several options exist for editing previously exisiting points. To begin editing points, click on the button Edit on the 3dMapper main menu. Make sure your point coverage is still marked for editing.



After you click edit, a table containing a list of points and their coordinates and labels will appear. By default, the first record in the table is hightlighted. Notice that the corresponding point on the local view has changed colors as well. Now, you can move, delete, or relabel a point. You can also select points in the local view by highlighting a particular row in the Point Information Table.

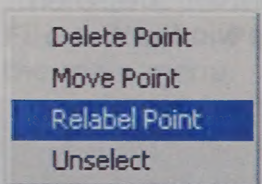


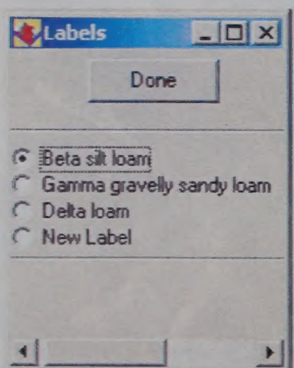
Moving Points: First, select the point you want to edit (left-click). Right-click on the point to access the edit menu. Then, click Move Point and drag the point to its new location.

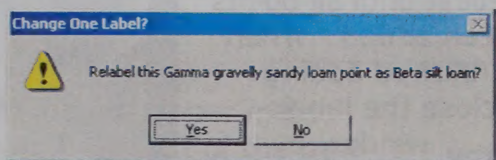


Notice the new position of the Beta silt loam type location.

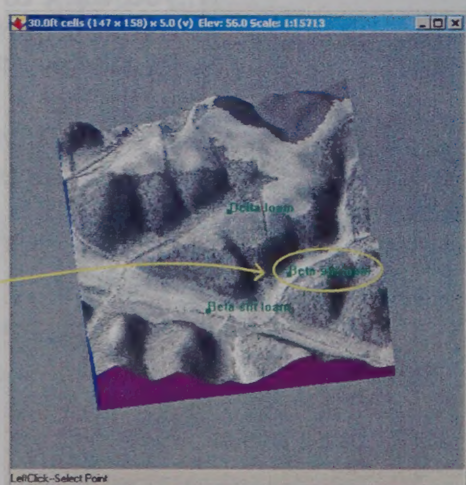
Relabeling Points: First select the point you want to edit (left-click). Then, right-click on the point to access the edit menu. Choose Relabel Point. Select an existing label from the Labels window or create a new label (by clicking "new label"). When you're finished, click done. Then, click Yes in the Change Label window to complete the process.





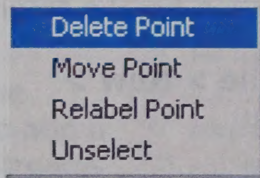


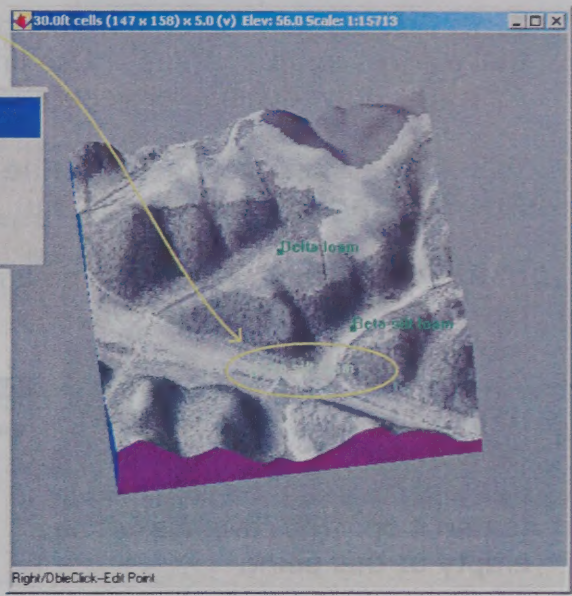
Notice the new label...

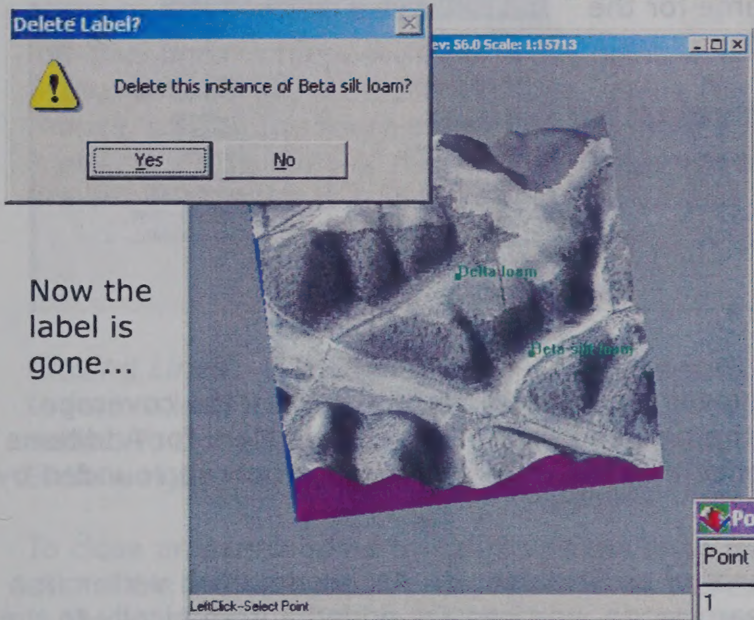


IV. Creating and Editing Data with 3dMapper: *Points*

Deleting Points: First select the point you want to delete (left-click). The selected point and label will turn a different color. Then, right-click on the point to access the edit menu. Choose Delete Point. Click Yes in the Delete Label window to complete the process.







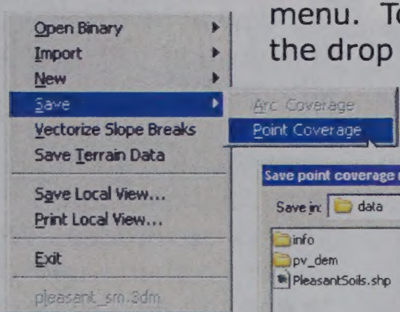
Now the label is gone...

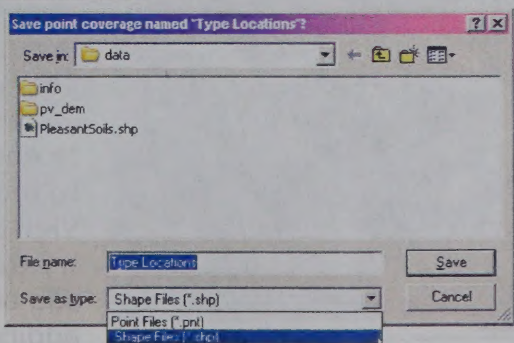
...and the Point Information table reflects the changes that have been made to the original Type Location coverage.

Point Information

Point No.	ID	Label	X	Y
1	1	Delta loam	712573.4	491521.6
2	2	Beta silt loam	713293.4	490741.6

There are two options for *Saving* coverages: Ascii text files and ArcView 3.x shapefiles. To save a point file, choose **File > Options > Save > Point Coverage** from the main menu. To save a point file as a shapefile, choose Shape Files (*.shp) from the drop down menu that appears when you click on the triangle to the right of the Save as type: box. Browse to the location you want to save your data, enter a different file name if desired, and click Save. To save a point file as an Ascii text files, choose Point Files (*.pnt) from the dropdown menu. Change the location and name if necessary and click Save. Click save again when prompted with a *.lab file rhe same name (Ascii point files consist of a *.pnt file with the x,y coordinates of a point and a *.lab file that contains the point label.

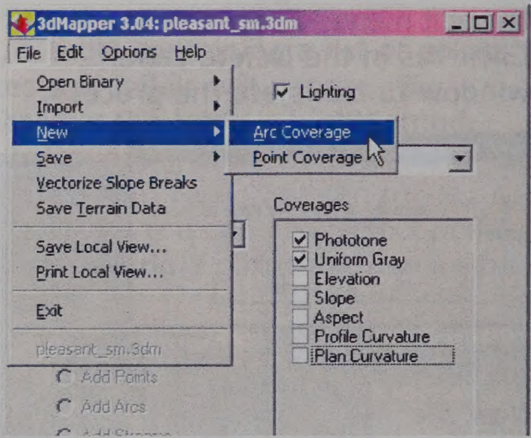




IV. *Creating and Editing Data with 3dMapper:* Lines

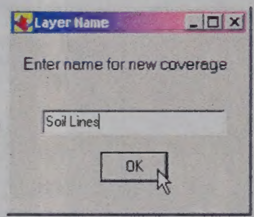
Line Coverages contain an identifying number and a list of the x,y coordinates for all the vertices in an arc (line). Use lines to delineate map units, digitize rivers or roads, or draw geology or vegetation breaks among other things.

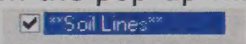
To create a line coverage, click **File > New > Arc Coverage** on the main menu.



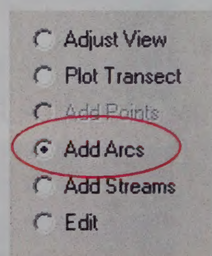
In the Layer Name window, type a name for the new coverage. Then click OK.

The new coverage will be added to the list of coverages in the 3dMapper main menu. Click on the box to the left of the new coverage to turn it on. The coverage will be empty at this point.



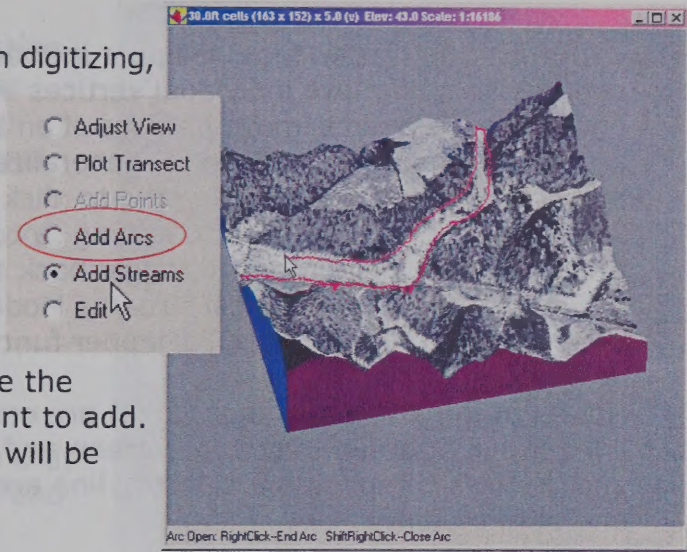
Before you begin adding data to the new line coverage, you must mark the coverage for editing. To do this, right-click on the new coverage, then choose Mark for Additions or Edits from the pop-up window. Notice that the coverage name is now surrounded by asterices... 

Lines can be added in two ways: as Arcs or as Streams. In Arc mode, each vertex in a line must be added manually. In Stream mode, vertices are added automatically to the line as the mouse moves. In both cases, left-click to start the line and double-click or right-click to end it. Use Shift + right-click to close a line (essentially, to create a polygon).



Adding Arcs: To add an arc to the new coverage Soil Lines, first click on Add Arcs on the 3dMapper main menu. Then, left-click in the local view window at the location where you want to start the arc. Continue left-clicking to add additional vertices. When you're finished, right-click to end the arc. Remember to toggle between Adjust View and Add Arcs...if you try to adjust the view in add arc mode, you'll end up adding another arc.

IV. Creating and Editing Data with 3dMapper: Lines

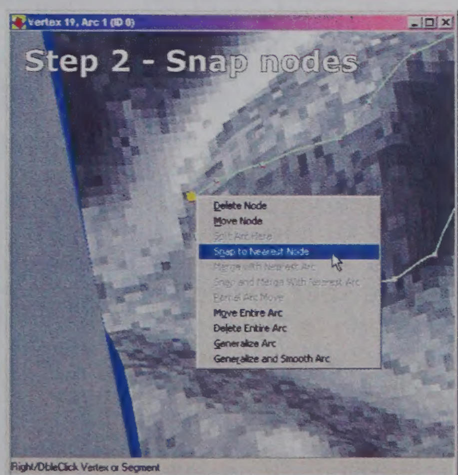


Adding Streams: Adding streams, or stream digitizing, allows the user to add a continuous line just by moving the mouse.

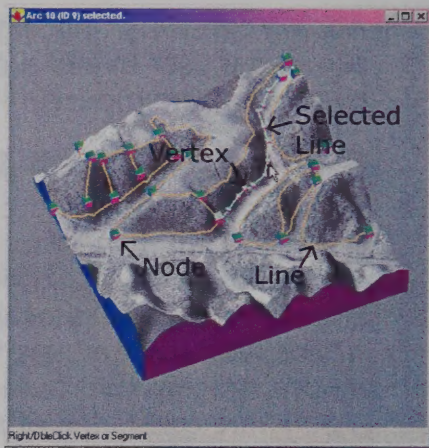
Points are added automatically as the mouse moves across the screen. To add a line in stream mode, first click Add Streams on the 3dMapper main menu. Then, left-click once in the local view at the point where you want to start the new line. Move the mouse, tracing the route of the line you want to add. A pink line consisting of numerous vertices will be drawn. Right-click to end the line.

Closing Lines: It is often necessary to close lines...essentially, to form a loop in which the line begins and ends at the same node. To close a line you're currently digitizing, use Shift + right-click to end the line.

To close an existing line to itself, use the snap functions accessible in Edit mode. First, zoom in on the existing line in the local view. Choose Edit from the 3dMapper main menu. Then, select the line you want to edit (left-click). Right-click on the node you want to move...the node will turn yellow. Choose *Snap to Nearest Node* from the pop-up menu. Now, the line is closed.



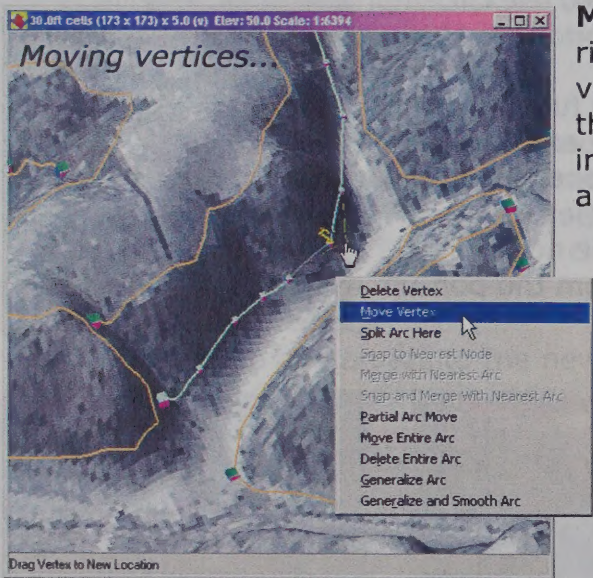
IV. *Creating and Editing Data with 3dMapper:* Lines



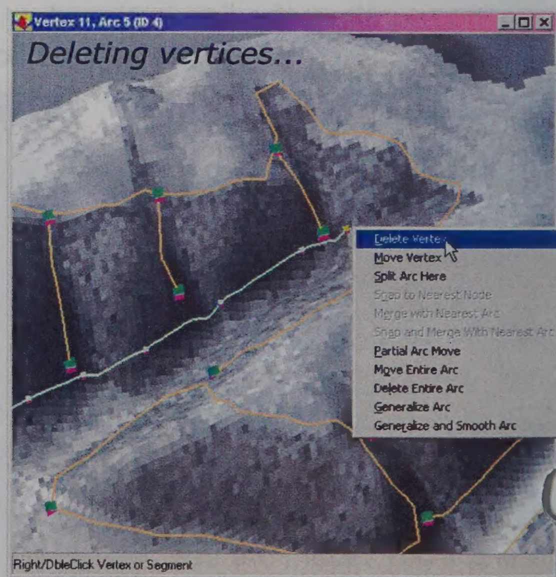
Other Editing Options in 3dMapper include the abilities to add, delete, and move individual vertices in an arc, move and delete entire arcs, move portions of an arc, merge multiple arcs into a single arc, split arcs, generalize and smooth arcs, and snap nodes together. Be sure to click Edit on the 3dMapper main menu prior to editing a coverage to access the edit tools. Remember to toggle back and forth between the Edit Mode, the Add Arcs/Streams Mode, and the Adjust View mode to access other 3dMapper functions.

Note: In this example, lines (arcs) are orange, selected lines are light green, nodes are green and purple boxes, and vertices comprising a selected line are light green and purple points.

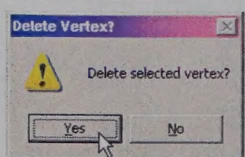
Editing Vertices: All the points that make up a line, with the exception of the starting and ending points, are called vertices. To move or delete a vertex, first select the line that contains the vertex (left-click), then right-click on the vertex that will be edited.



Move a vertex by first selecting a line and right-clicking on the vertex (notice the selected vertex is bright yellow). Choose Move Vertex from the pop-up window. The arrow pointer will turn into a hand...use the hand to drag the vertex to a new location.

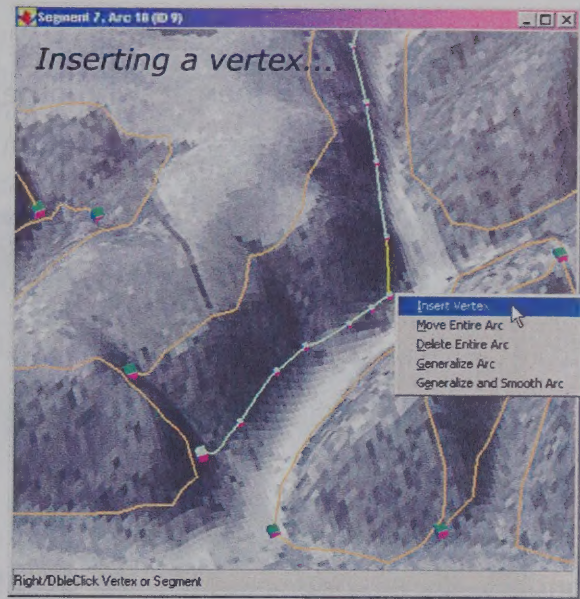


Delete a vertex by first selecting a line and right-clicking on the vertex (notice that the selected vertex is bright yellow). Then, choose Delete Vertex from the pop-up window. Click Yes in the Delete Vertex window to complete the process.)



IV. *Creating and Editing Data with 3dMapper:* Lines

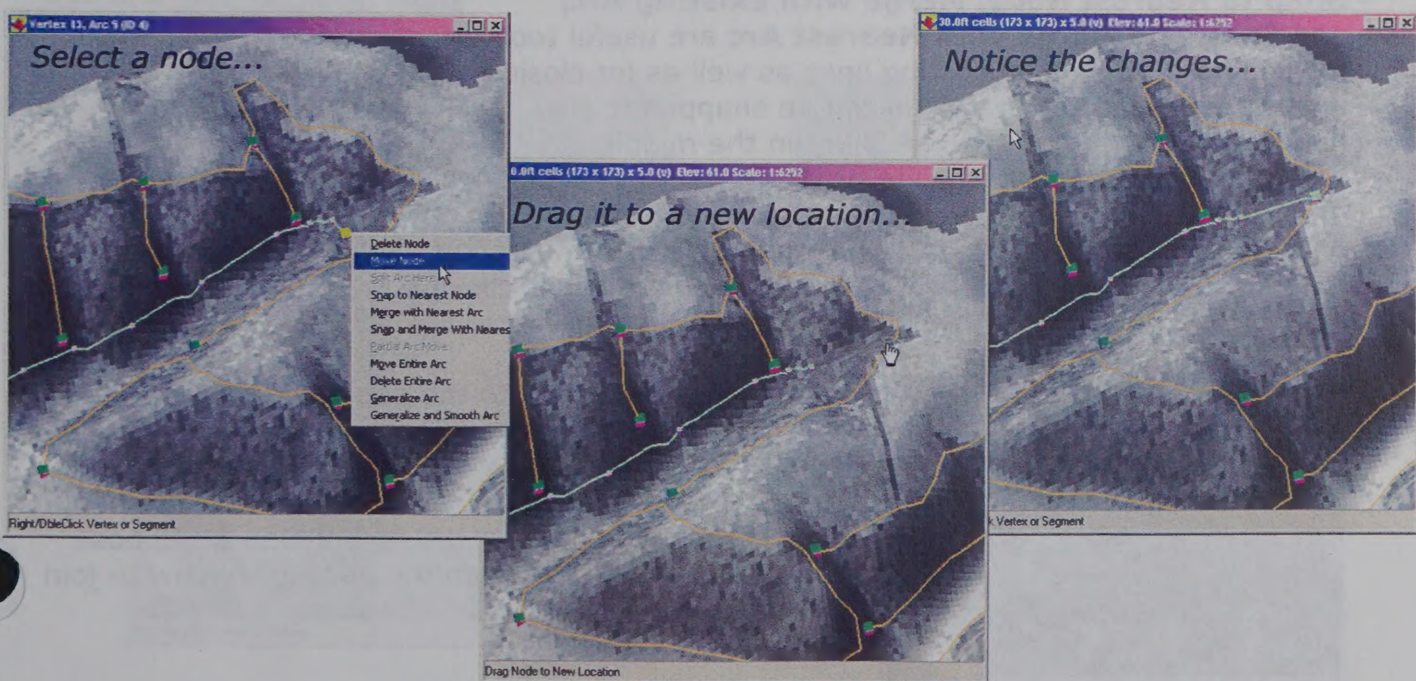
Insert an additional vertex by first selecting a line. Then, right-click on the line. Choose Insert Vertex from the pop-up window, then left-click to place the new vertex. Use additional vertices to add shape to a line.



Editing Nodes: Nodes are special vertices that begin and end lines. Nodes can be deleted and moved. Other functions that involve nodes include snapping lines together and merging two lines together.

Delete a node by first selecting a line and then right-clicking on the node (notice that the selected node has turned bright yellow). Choose Delete Node from the pop-up window.

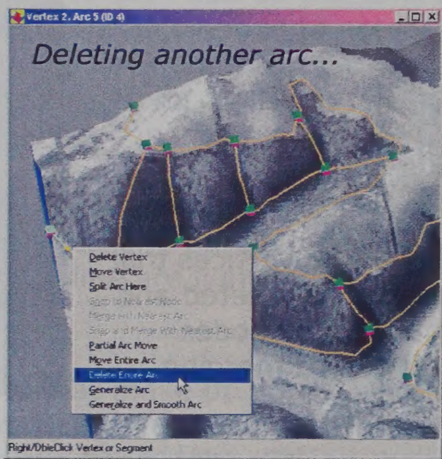
Move a node by first selecting a line and then right-clicking on the node (notice that the selected node has turned bright yellow). Choose Move Node from the pop-up window. The arrow pointer will turn into a hand. Left-click on the node, then drag the node to its new location.



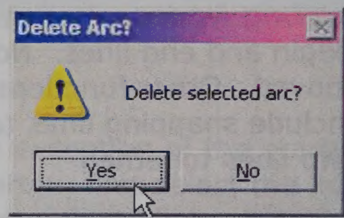
IV. *Creating and Editing Data with 3dMapper:* Lines

Editing Entire Lines: Entire lines can be deleted, moved, split into two lines, snapped to other lines, or merged with other lines.

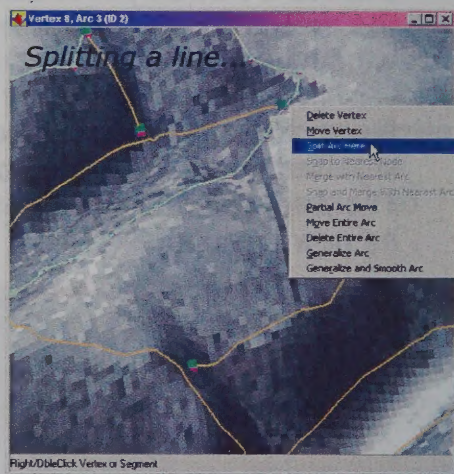
Delete a line in one of two ways: Select an arc to delete by left-clicking on the arc.



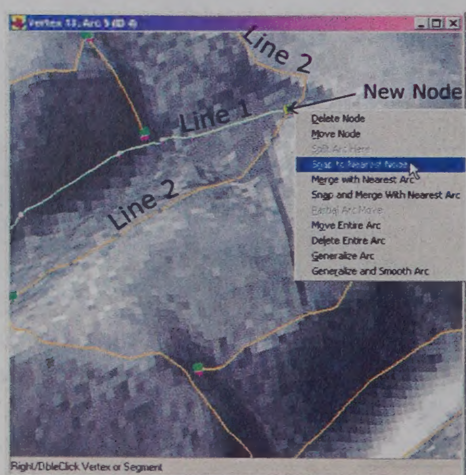
Then, either right-click on the line and choose Delete Entire Arc or right-click on a node or vertex and choose Delete Entire Arc. Then click Yes in the Delete Arc window.



Lines can be **Split** into two pieces at any vertex. If there is not a vertex at the point where the line is to be split, insert one. Then, after making sure the line is selected, right-click on the vertex at which you want to split the line. Choose Split Arc Here to split the line.



Snap to Nearest Node, Merge with Existing Arc, and **Snap and Merge with Nearest Arc** are useful tools for joining new lines to existing lines as well as for closing arcs (see Closing Lines). Lines can be snapped to the end of another line or to somewhere in the middle of a line, provided a node exists.

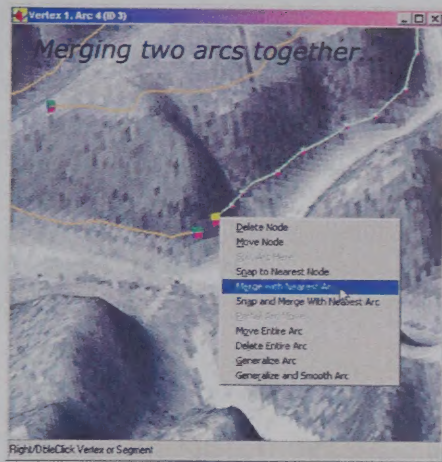


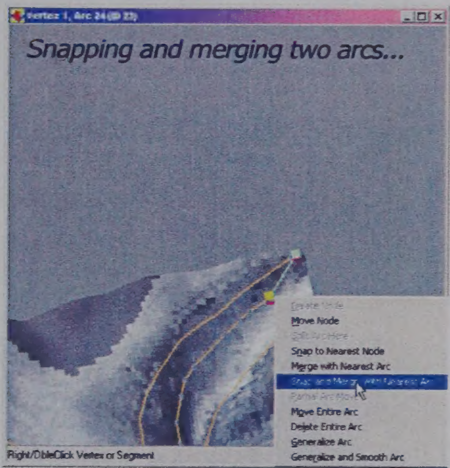
To snap an arc to the *end* of another arc, just select the arc to be edited, right-click on the node to be moved, and choose Snap to Nearest Node from the pop-up menu.

To snap a line (Line 1) to the *middle* of another line (Line 2), first create a node at that location by *Splitting* Line 2 (you may need to add a vertex as well). Once you've created a node in Line 2, select Line 1. Then, right-click on the node at the end of Line 1. Choose Snap to Nearest Node from the pop-up window to join the lines.

IV. *Creating and Editing Data with 3dMapper:* Lines

Merge with Nearest Arc lets you join two adjacent lines together. The common node between the two lines will be deleted. To merge a line to another existing line, select the line you want to edit, right-click on the node you want to move, then choose Merge with Nearest Arc from the pop-up menu to complete the action.

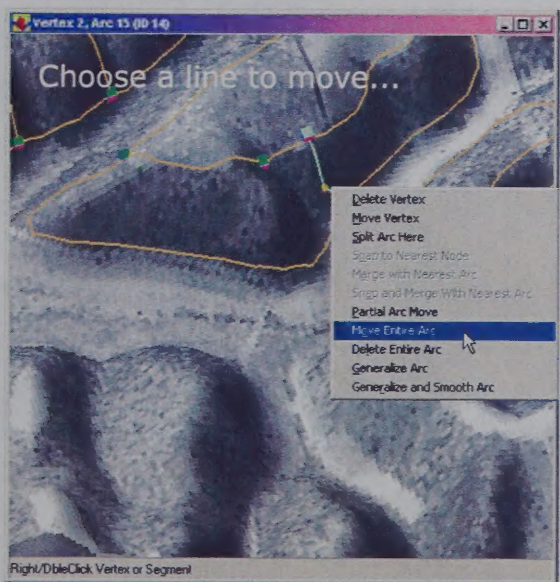




It's important to pay attention to snapping and merging arcs during the editing process if you plan to create polygons or networks from the arcs in the future!

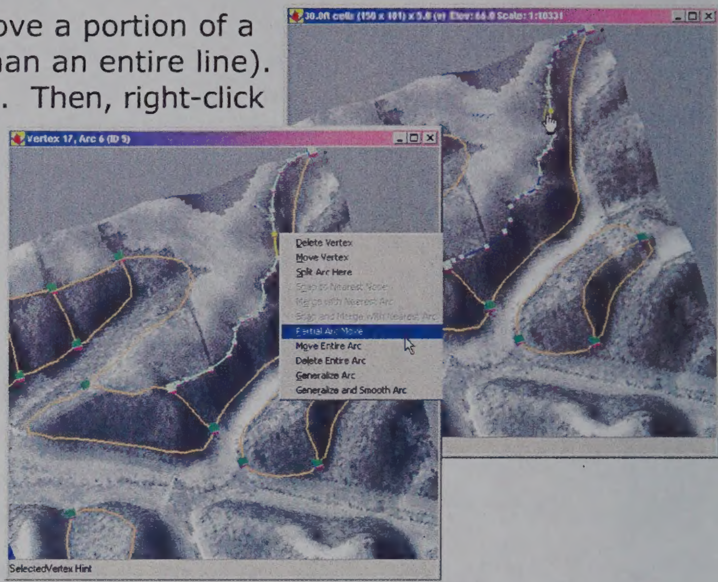
Snap and Merge to Nearest Arc is useful in cases where you want to append another line to the end of an existing line. First, add a line near the end of an existing line. Making sure the new line has been selected, right-click on the node closest to the preexisiting line. Then, choose Snap and Merge to Nearest Arc from the pop-up menu to complete the action.

Moving Lines: To move an entire line, first select the line. Then, right-click on the line and choose Move Entire Line from the pop-up window (you'll see different menus depending on if you right-click on a vertex or a line segment). The arrow pointer will turn into a hand...grab the line and drag it to a new location, making sure to snap it to adjoining lines if necessary.



IV. *Creating and Editing Data with 3dMapper:* Lines

Moving Lines: Sometimes it's nice to move a portion of a line (more than a single vertex but less than an entire line). To move part of a line, first select the line. Then, right-click on a vertex in the portion of the line you want to adjust and choose Partial Arc Move from the pop-up window. The arrow pointer will turn into a hand...grab the line and drag it to a new location. Notice that multiple vertices are effected.

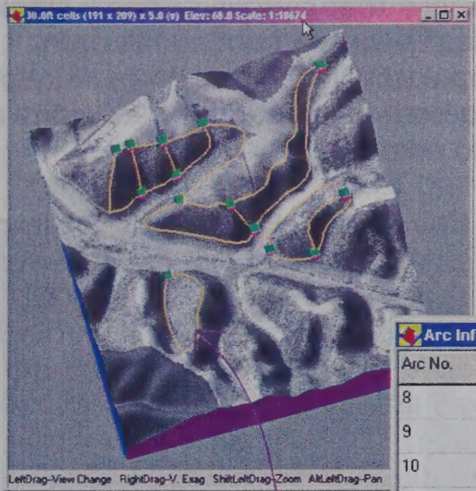


Generalizing and Smoothing Lines: Some lines, especially those created in Stream mode, have too many vertices. Others look may look jagged. 3dMapper can generalize lines using a user-specified tolerance and smooth lines to approximate hand-drawn curves.

To **Generalize** a line, select the line, then right-click. Choose Generalize Arc from the pop-up menu. The generalization process deletes vertices that fall within a user-specified distance of a series of line approximations. To adjust the tolerance (small values result in less generalization, large values in more), choose **Options > D-P Tolerance** from the main menu. Enter a new tolerance and click OK. Be careful, as once you generalize an arc, the only way to ungeneralize it is to undo the action or smooth the arc.

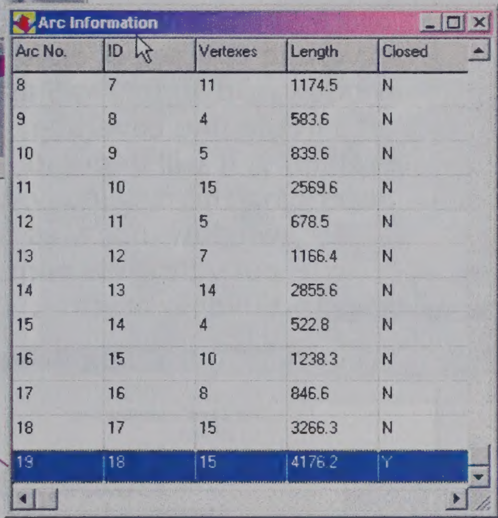
To Smooth a line, select the line, then right-click. Choose Generalize and Smooth Arc from the pop-up menu. The smoothing process adds extra vertices to a line to mimic a smooth line drawn by a cartographer. To smooth all the arcs in a coverage at once, right-click on the coverage in the main menu and select Generalize and Smooth Arcs.

IV. *Creating and Editing Data with 3dMapper:* Lines



The Soil Lines coverage after editing...remeber the orignal coverage? Note that all lines in the coverage connect to other lines

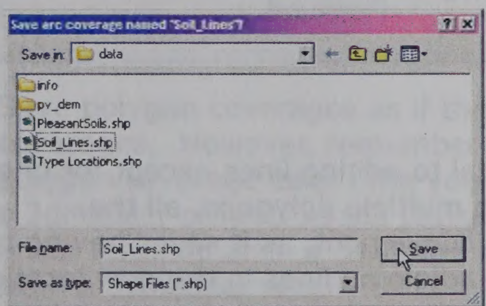
Lines also have an associated information table called an Arc Information Table. The Arc Information Table contains the Arc Number, Arc ID, number of vertices, length, and closure state of each line in the coverage.



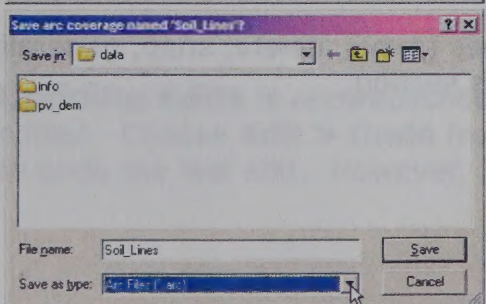
Arc No.	ID	Vertexes	Length	Closed
8	7	11	1174.5	N
9	8	4	583.6	N
10	9	5	839.6	N
11	10	15	2569.6	N
12	11	5	678.5	N
13	12	7	1166.4	N
14	13	14	2855.6	N
15	14	4	522.8	N
16	15	10	1238.3	N
17	16	8	846.6	N
18	17	15	3266.3	N
19	18	15	4176.2	Y

Only Arc No. 19 is closed according to the Arc Information Table, even though we know all of the lines are connected to each other. 3dMapper only considers a line "closed" if its starting and ending node are the same.

Saving Line Files: Line coverages can be saved as Ascii text files or ArcView 3.x shapefiles. To save a line file, choose **File > Options > Save > Arc Coverage** from the main menu. To save a shapefile, choose Shape Files (*.shp) from the drop down menu that appears when you click on the triangle to the right of the Save as type: box. Browse to the location you want to save your data, enter a different file name if desired, and click Save.



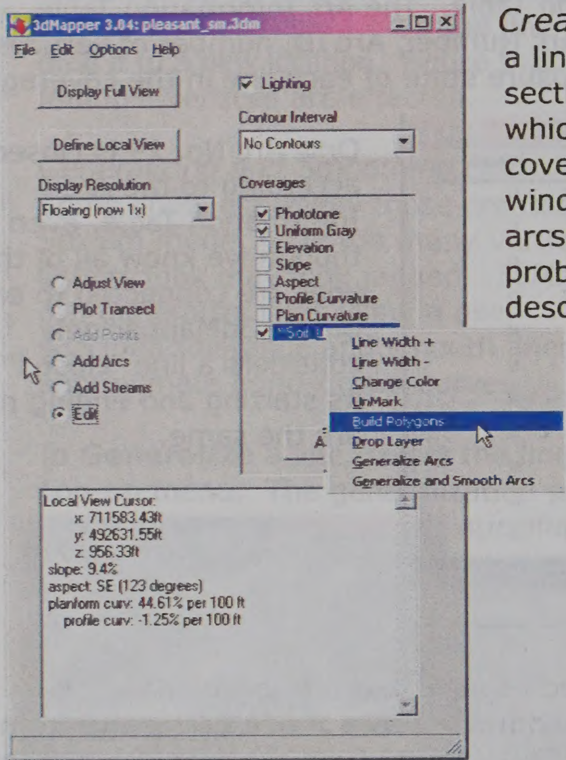
To save a 3dMapper line file, choose Arc Files (*.arc) from the dropdown menu. Change the location and name if necessary and click Save. It is good habit to save your edits frequently, just in case...



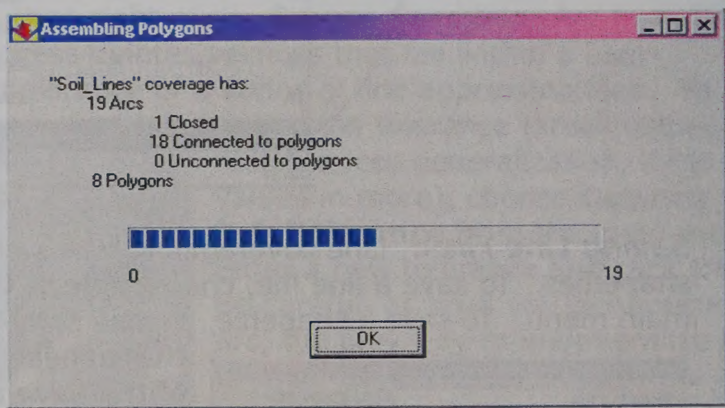
Shape File or Ascii Text File? Save point and line files as Shapefiles if you expect to use the data in ArcView or ArcGIS (but not ArcInfo workstation). Otherwise, you'll probably want to use an Ascii text file as most software packages can easily import a text file.

IV. Creating and Editing Data with 3dMapper: *Polygons*

Polygon Coverages are constructed from line coverages that contain either a single closed line or a number of lines connected at their nodes to form a continuous path. Lines often belong to more than one polygon (for example, the line separating a floodplain soil delineation from a terrace soil delieation belongs to both delineations). Polygons are drawn the same way as lines, but respond differently to editing.



Creating a Polygon Coverage: First, create or import a line coverage (the import process will be discussed in section five). Then, click on the line coverage for which you want to create polygons. Right-click on the coverage and select Build Polygons from the pop-up window. 3dMapper will assemble polygons from the arcs in the line coverage. If 3dMapper encounters problems, it will generate an error message box describing them. Finally, the Assembling Polygons window indicates the number of arcs and poltygons encountered and/or created in the building process. Click OK once you've read it.



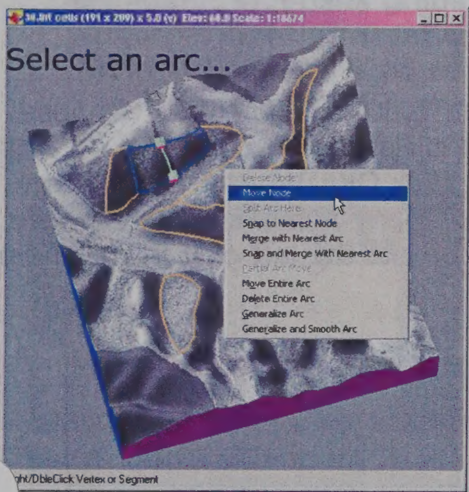
Note: If you edit a polygon coverage as arcs, you'll need to rebuild it.

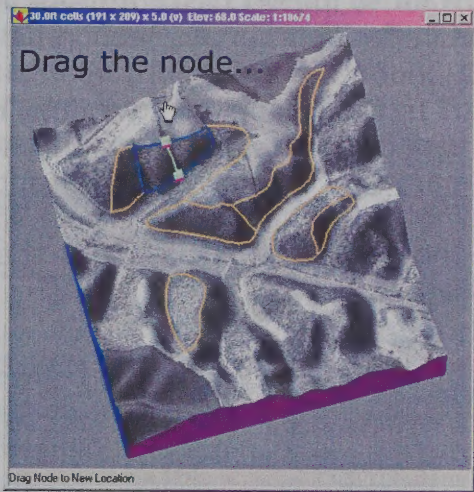
Editing Polygons: Editing polygons is almost identical to editing lines except for one important difference...if you move a node attached to multiple polygons, all the lines attached to that node will move as well. This is convienent, as it saves having to move each line individually and reconncecting all the adjoining lines in the new location.

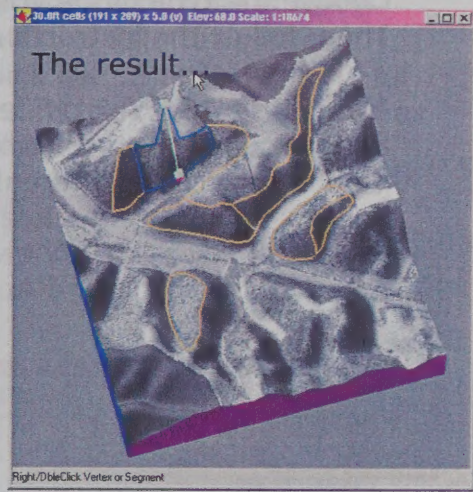
Edit vertices (move, insert, and delete) and entire lines (move, delete, snap, generalize, smooth, etc.) in the manner described in the previous section.

IV. Creating and Editing Data with 3dMapper: Polygons

Editing Polygons - moving nodes: To move a node, first select a line attached to the node. Notice that the selected line turns light green while all the other lines connected to the node turn blue. Then, right-click on the node and choose Move Node from the pop-up menu. The arrow pointer will turn into a hand. Grab the node and drag it to a new location. Not only does the position of the selected line change, so do the positions of all the lines attached to the node. Connectivity to the node is also maintained.







Once a coverage has been built, the Arc Information Table will contain additional information regarding polygons. Two new columns, Left Polygon and Right Polygon, will appear. These columns indicate which polygon will be found to the left and right of a given line. 3dMapper uses this information to assemble and manage polygons.

Save polygon coverages as if they were arc coverages. However, remember to build a polygon coverage each time you add it to a 3dMapper project, as the polygon information is not retained once a coverage is dropped from a 3dMapper session.

Arc Information

Arc No.	ID	Vertexes	Length	Closed	Left Polygon	Right Polygon
1	0	10	1538.0	N	0	none
2	1	2	276.6	N	none	0
3	2	2	690.0	N	1	0
4	3	2	570.8	N	6	1
5	4	5	905.3	N	none	2
6	5	22	3367.0	N	none	3
7	6	10	2002.3	N	none	4
8	7	11	1174.5	N	none	5
9	8	4	656.1	N	none	1
10	9	5	789.3	N	none	6
11	10	15	2569.6	N	none	none
12	11	5	678.5	N	1	none
13	12	7	1166.4	N	6	none

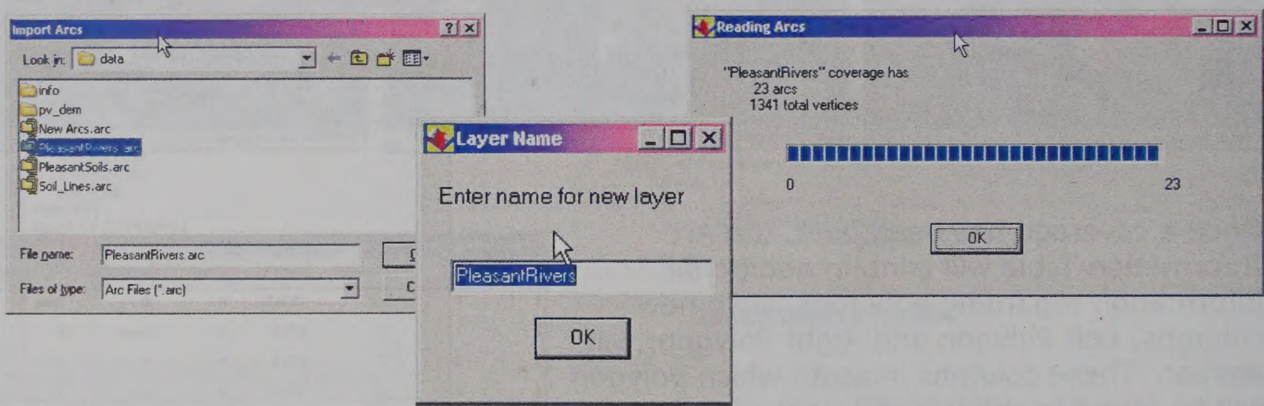
Undoing Edits is accomplished in the same manner, regardless of the feature being edited. Choose **Edit > Undo** from the main menu, or press Control + z on the keyboard to undo the last edit. However, 3dMapper can only reverse the most recent action.

IV. *Adding Additional Data Layers: Importing Files*

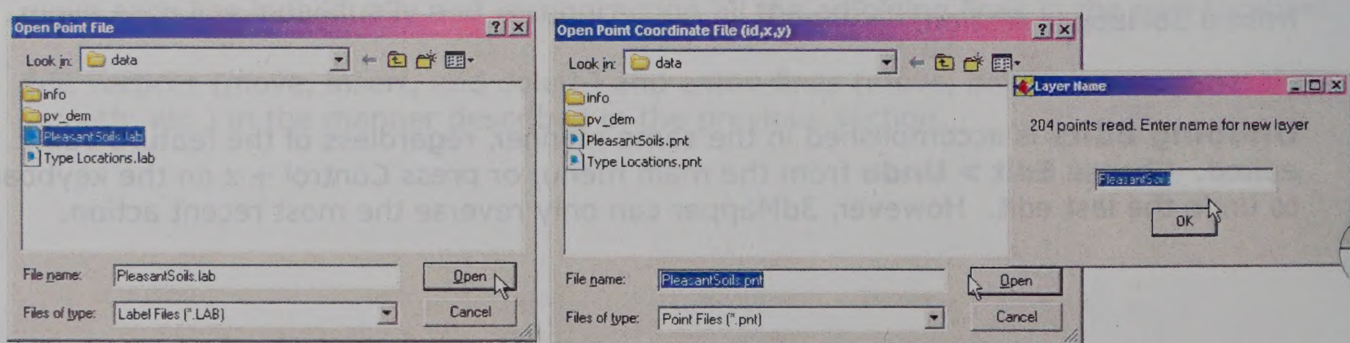
3dMapper can import raster files in ASCII format (*.asc) created from the ArcInfo `gridascii` command, ArcView 3.x shapefiles (points and lines), and Ascii point and line files created from the ArcInfo `ungenerate` command. Importing Base files was covered in Section I.

To import a file into a 3dMapper session, click **File > Import** on the main menu. Choose the type of file you want to import: Ascii Arc, Ascii Point, Raster, or Shape File. Then, follow the instructions in the appropriate section below.

Importing ASCII Arc Files: In the Import Arcs window, navigate to your data. Choose the *.arc file (or other ascii text file) you want to import and click open. Accept the default name or specify a different name for the new arc layer and click OK. When the coverage finishes importing, the Reading Arcs window will indicate how many arcs and vertices were imported. Click OK. View the new layer by clicking in the box to the left of it in the main menu and then clicking Apply.



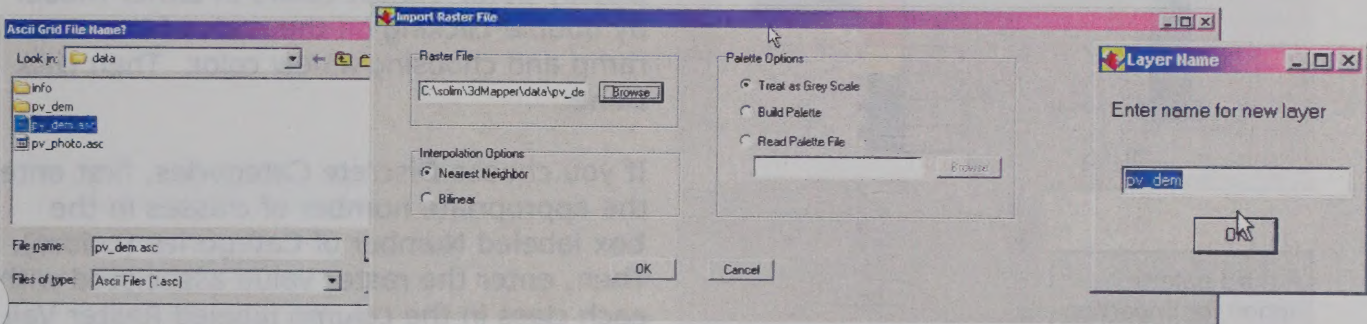
Importing ASCII Point Files: Navigate to your data directory in the Open Point Files window. Choose the *.lab (or other ascii label file) file you wish to open and click Open. In the Open Point Coordinate File window, select the corresponding *.pnt file (or other ascii coordinate file) and click Open again. Accept the default name or specify another name for the new point layer in the Layer Name window, then click OK. To view the new layer, click in the box to the left of it in the main menu and then click Apply.



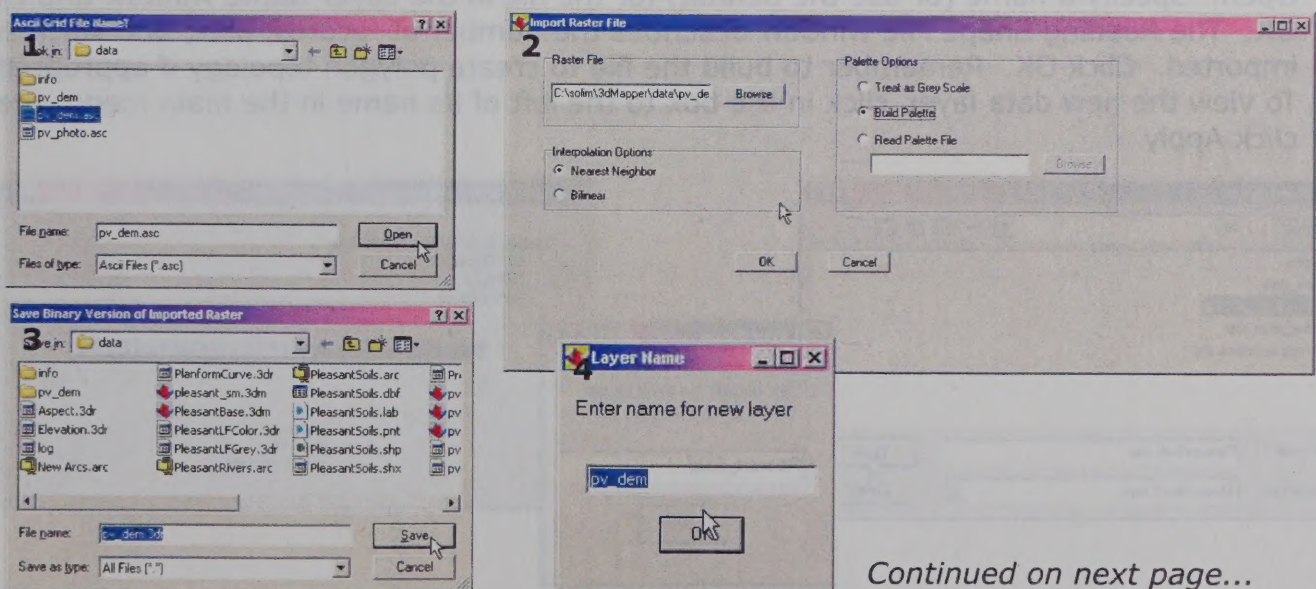
IV. ***Adding Additional Data Layers:*** *Importing Files*

Importing Raster Files: Raster files can be imported in grey scale or in color. If the file is imported in color, a new color palette can be created during the import process or an existing palette file can be accessed at this point.

To import a raster file in *Grey Scale*, navigate to your data directory in the Ascii Grid File Name window and select an Ascii grid file (*.asc ~ ascii grid files can be easily generated from any grid file in ArcInfo) to open. Verify that the correct file is being imported and that Treat as Grey Scale is marked under the list of Palette Options. Nearest Neighbor is an acceptable Interpolation Option. Click OK. Specify a name for the raster file in the Layer Name window and click OK. To view the file, click in the box to the left of the new coverage name in the main menu and then click Apply.



To import a raster file in *Color*, navigate to your data directory in the Ascii Grid File Name window and select an Ascii grid file (*.asc ~ ascii grid files can be easily generated from any grid file in ArcInfo) to open. Verify that the correct file is being imported. Click on Build Palette under the list of Palette Options. Nearest Neighbor is an acceptable interpolation method. Click OK. Click OK again in the Save Binary Version of Imported Raster window. Then, specify a name for the new raster file.



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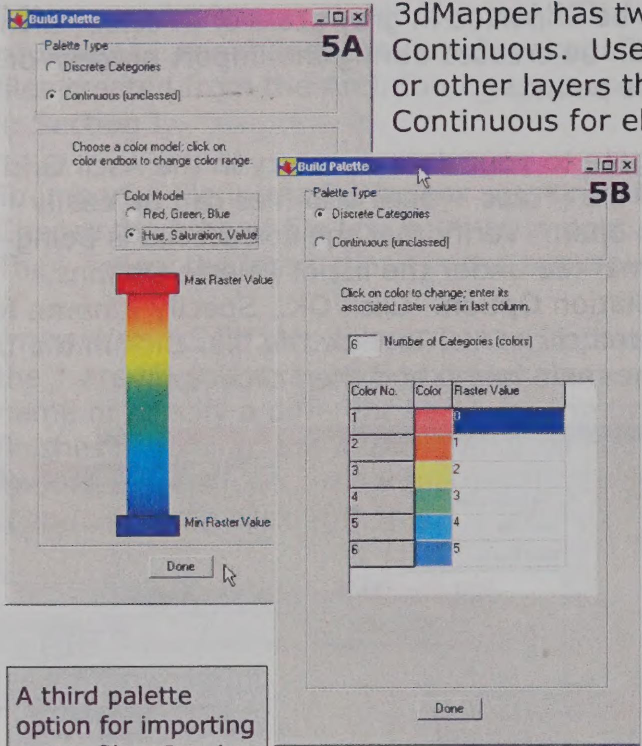


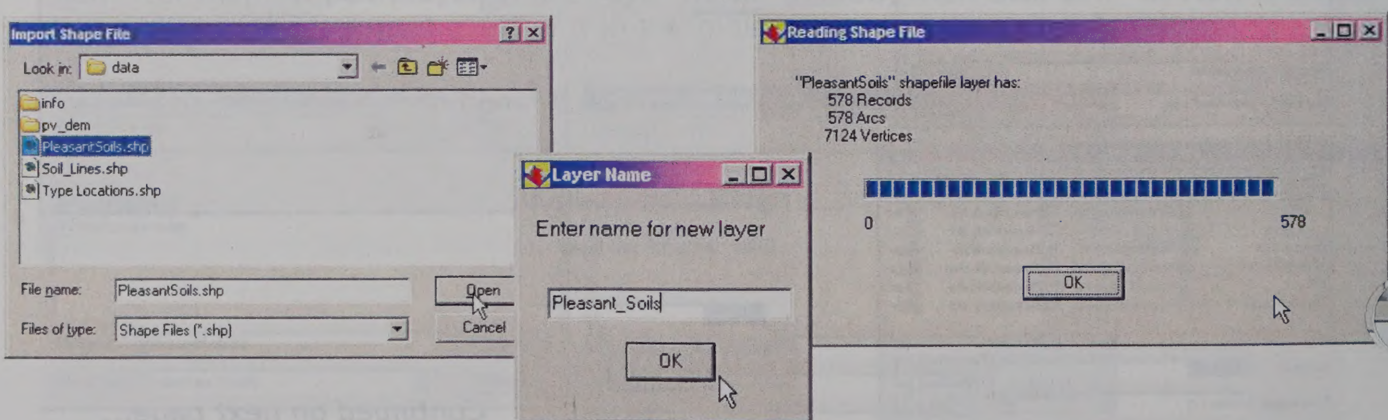
3dMapper has two palette types: Discrete Categories and Continuous. Use Discrete Categories for vegetation, geology, or other layers that lend themselves to discrete classes. Use Continuous for elevation data, precipitation, or other data that varies smoothly and continuously across a region.

If you choose Continuous, select either the RGB or HSV color model. By default the RGB color model uses variations in two colors to display data while the HSV color model uses variations in six colors to display data. Adjust colors in either model by double-clicking on the ends of the color ramp and choosing a new color. Then click Done.

If you choose Discrete Categories, first enter the appropriate number of classes in the box labeled Number of Categories (colors). Then, enter the raster value associated with each class in the column labeled Raster Value. Finally, select colors by double-clicking on each color chip and choosing a color from the Color Palette. Then click Done. To view the new raster data layer, click in the box to the left of its name in the main menu, then click Apply.

A third palette option for importing raster files, Read Palette File, is discussed in the 3dMapper help file.

Importing Shapefiles: To import a shapefile, first navigate to your data directory in the Import Shape Files window. Select the shapefile (*.shp) you want to import and click Open. Specify a name (or use the default) for the file in the Layer Name window and click OK. The Reading Shape File window describes the number of records, arcs, and vertices imported. Click OK. Remember to build the file to create polygon topology if appropriate. To view the new data layer, click in the box to the left of its name in the main menu, then click Apply.



PRODUCT
DEVELOPMENT

Product Development

Pete Biggam
Soils Program Leader
National Park Service
Denver, CO
pete_biggam@nps.gov

Advanced Technology in Soil Mapping

"We know more about the celestial bodies above than the soils underfoot"

Leonardo Da Vinci

Advanced Technology in Soil Mapping

What is a Product ????

"Something resulting from a set of conditions"

Advanced Technology in Soil Mapping

$$E=Mc^2$$

That's Right Albert, but next time show your work!

We're like Albert, we have solved the problem, but have done little to provide all of the intrinsic knowledge applied, and informative products developed and utilized within the process of completing a soil survey to National Cooperative Soil Survey Standards

Specify product needed
obtain pedon/transect
data, ~~[illegible]~~ Digital products,
Access database, ~~[illegible]~~ ArcView
GIS/remote sensing layers
developed for survey,
Specify interps, [illegible]

Product Development

Lesson Plan Objective:

Given digital geospatial data and related attribute database, develop several examples of information products based upon meeting various customer needs.

Information products include:

- *Tabular output/reports*
- *Visualization of information*
- *Data aggregation -> Information*
- *Data manipulation -> Information*

3'

Product Development

Why is this important?

We need to have the ability to develop "products" to meet various customer needs in our ever-changing world

Product Development

What have we been producing?

- **Past** – Soil Survey Report, Soil Atlas Sheets

- **Present** – Soil Survey Report (hardcopy and digital), Soil Atlas Sheets (hardcopy and digital), Soil geospatial database with soil attribute database (SSURGO) that can be used in GIS

- **Future** – Similar products but with more flexibility to provide any/all of the actual components that are developed within the soil survey process, as well pursue soil visualization products

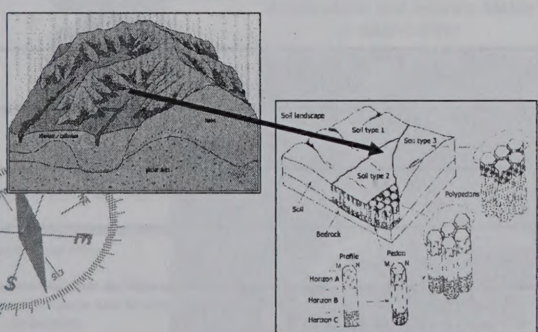
3-D Mapper or Geo Book

Future Products

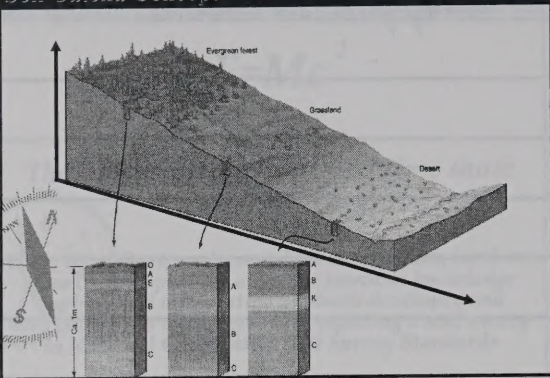
Need to consider making available all of the components used or developed within the soil survey process

✓Soil – Landscape – Vegetation model
✓Soil catena concepts
✓Soil forming factors as separate geospatial themes
✓Locations and attributes of all soil observations;
- Type pedons and supporting pedons
- Transects/Traverses
- Soil analyses
- Soil – crop yield correlation
- Soil – pasture correlation
- Soil – range correlation
- Soil – woodland correlation

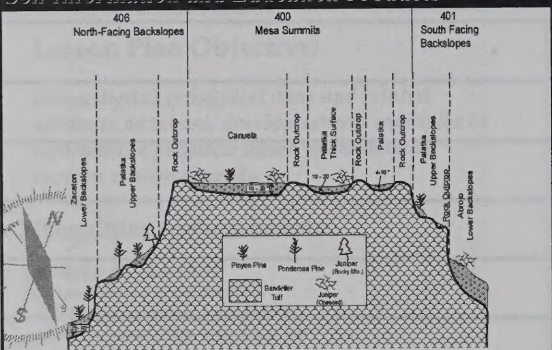
Soils and Landscapes



Soil Catena Concept



Soil Information and Education Products



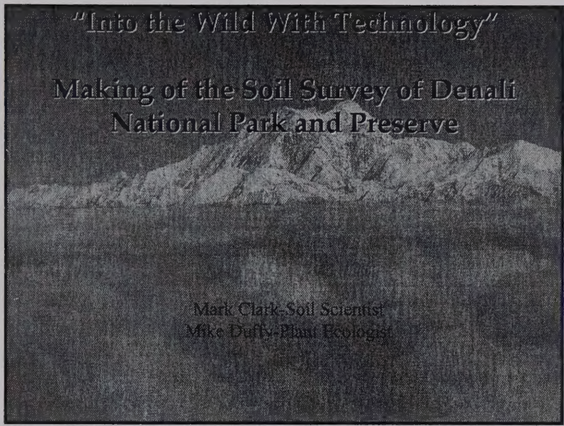
Soil/Landscape Genetic Key from Bandelier National Monument, New Mexico

Future Products

"Also need to take advantage of current tools to improve upon the delivery and utilization of our soil survey products"

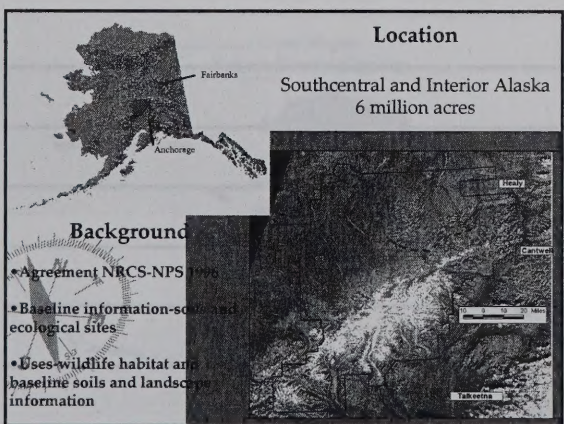
ERDAS Imagine
ARC GIS
ArcView
Soil Data Viewer
Terrestrial Ecosytem Unit Inventory (TEUI) Toolkit
3DMapper
MS Access and National Soil Information System (NASIS) SSURGO Templates

Do we need this portion of presentation?. Need not related to products, Provide some of this time for other needs. See what students feed back



"Into the Wild with Technology"

- ►Background and specifications
- ►Overview of Denali National Park
- ►Methods and technology used
- ►Applications and Products

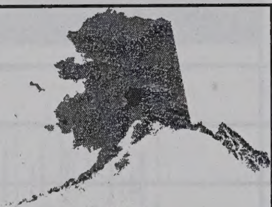


Product Development

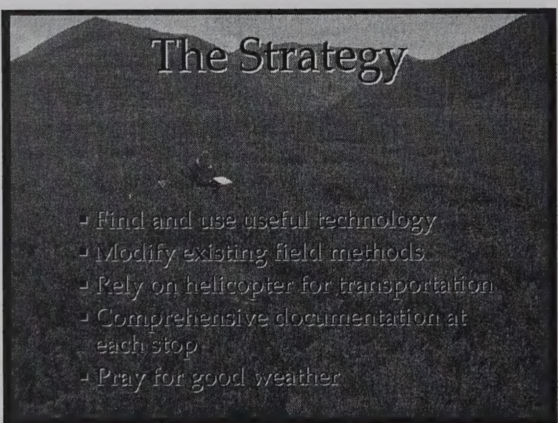
(NRCS provides NPS)

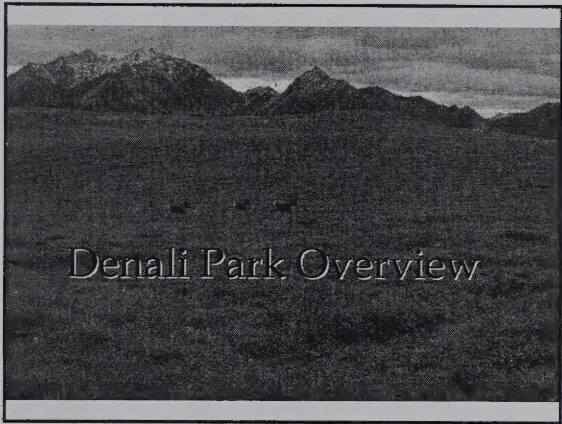
- Physiographic map (1:250,000)
- Detailed soils map (1:63,360) SSURGO
- General GIS map themes (1:250,000)
- Copy of the field database (MS Access)
- Geospatial locations of all pedons, transects, soil – veg correlation sites, lab sample sites
- Soil properties and interpretations (NASIS)
- Ecological site descriptions including PNC and seral communities
- Complete ecological hierarchy (ECOMAP)
- Complete in 6 field seasons (1997-2002)

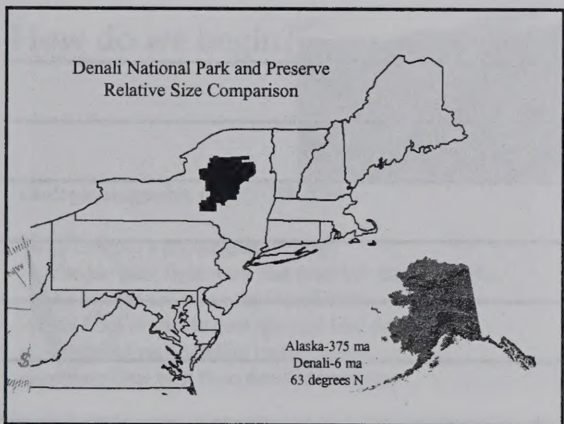
The Challenges

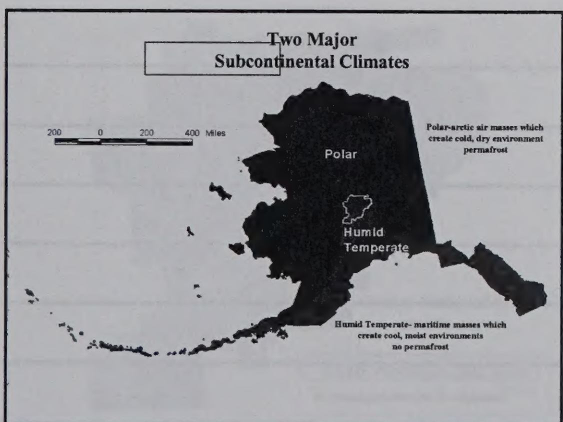


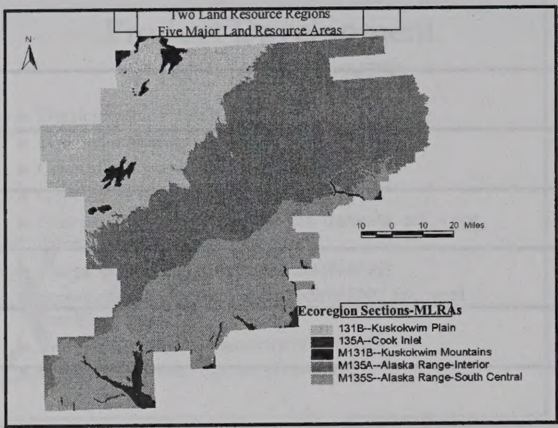
- No adjoining surveys or established soil series-several new suborders proposed
- Large and inaccessible-only one road in the park
- Little available park-wide information
  - 104 GIS layers available for Yellowstone-rule based project
  - Denali -two layers
    - Statewide geology-very general
    - General Landcover-only included a portion of Denali

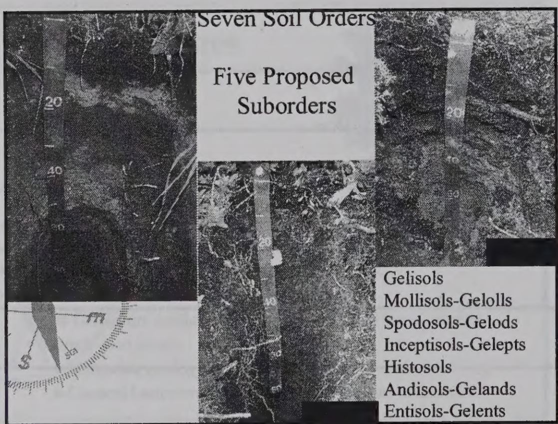


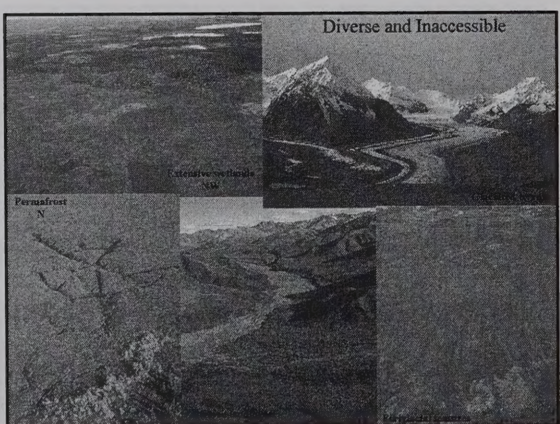

Denali Park Overview

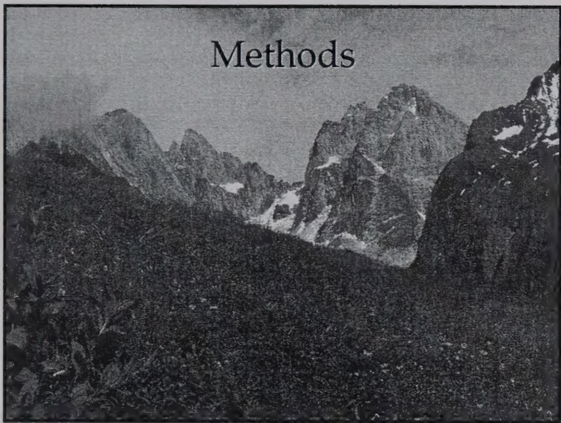

Denali National Park and Preserve
Relative Size Comparison
Alaska-375 ma
Denali-6 ma
63 degrees N


Two Major
Subcontinental Climates
200 0 200 400 Miles
Polar
Humid
Temperate
Polar-arctic air masses which
create cold, dry environment
permafrost
Humid Temperate- maritime masses which
create cool, moist environments
no permafrost


Two Land Resource Regions
Five Major Land Resource Areas
N
10 0 10 20 Miles
Ecoregion Sections-MLRAs
131B--Kuskokwim Plain
135A--Cook Inlet
M131B--Kuskokwim Mountains
M135A--Alaska Range-Interior
M135S--Alaska Range-South Central


Seven Soil Orders
Five Proposed Suborders
Gelisols
Mollisols-Gelolls
Spodosols-Gelods
Inceptisols-Gelepts
Histosols
Andisols-Gelands
Entisols-Gelents

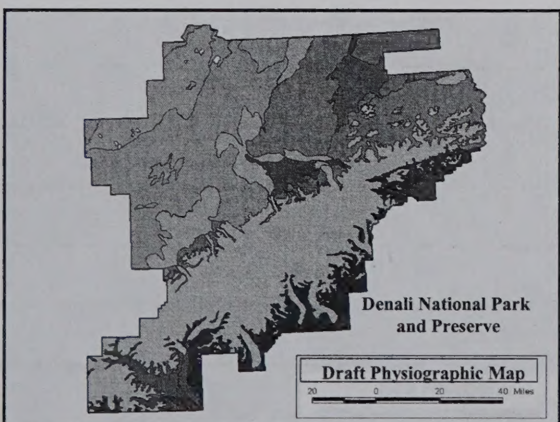

Diverse and Inaccessible
Permafrost



How do we begin?

Draft physiographic map (1:250,000)

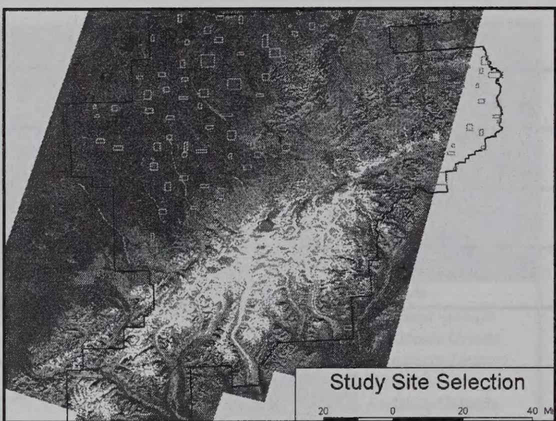
-Why develop a physiographic map?
  -Used to plan field work and establish mapping rules
  -An interim reference for Denali Park
-Made from available geologic and land cover info
  -Compiled on a satellite image mosaic
-Generate final map from detailed mapping

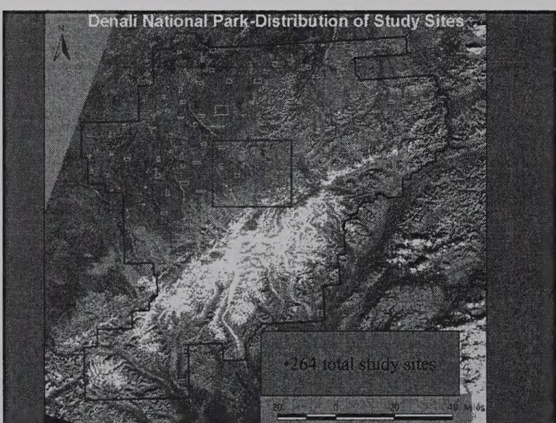


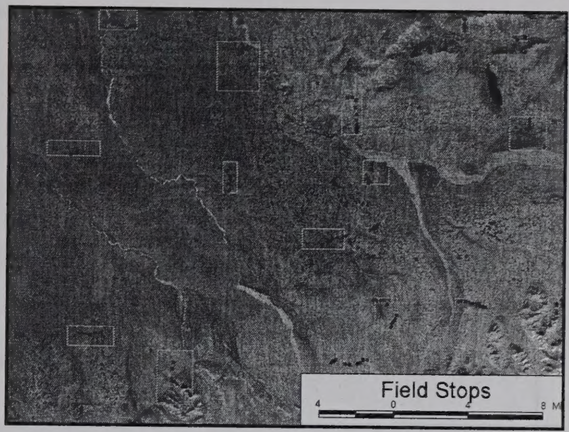
Methodology

Detailed Mapping
Preparing for the field

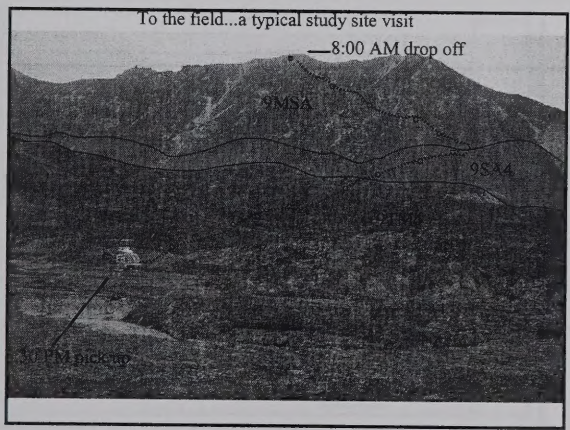
- Select a geographic area (1 ma) annually
- Pre-map using 1:60,000 AHAP CIR photos
- Select representative areas "Study Sites" on photos and satellite imagery to visit
  - Representative areas of from two to four delineations that can be visited in a day
- Obtain coordinates for helicopter navigation



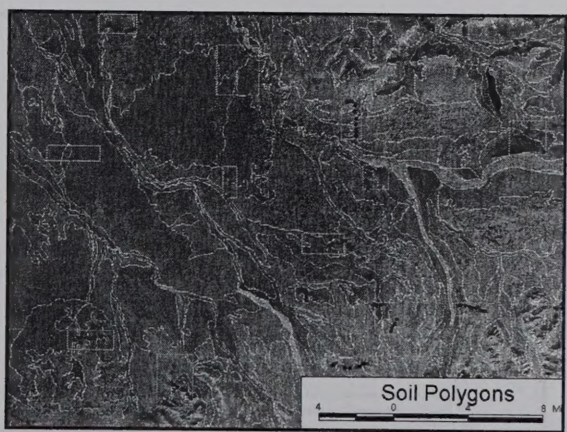




Field Stops



To the field...a typical study site visit
8:00 AM drop off
9MSA
9SA4
3:0 PM pick-up



Soil Polygons

Mapping Rules

Map Units

- Unique to a Section
- NSH name
  - 2FP3-Typic Cryofluvents-Typic Historthels-Oxyaquic Cryorthents Association
- Landscape name
  - 2FP3-Boreal Flood Plains and Terraces with Discontinuous Permafrost

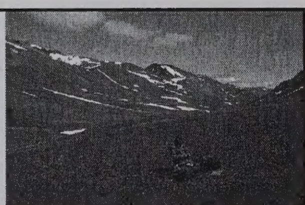
Component Example-

Map unit 2FP3

- Unique to a Section
- Landscape component name
  - Boreal-riparian scrub gravelly low flood plains
- NSH name
  - sandy-skeletal, mixed, calcareous Oxyaquic Cryorthents

Methodology

After the field work

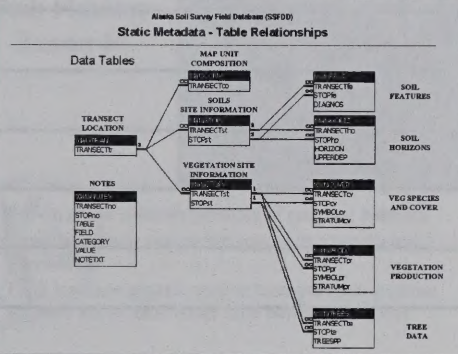


- Data input and analysis (MS Access)
- Re-stereo maps and finalize map unit assignments to all polygons
- Line transfer to 1:63,360 scale orthos, scanned and digitizing reviewed/edited
- Interim maps and database to NPS annually
- NASIS input

TWO DATABASES

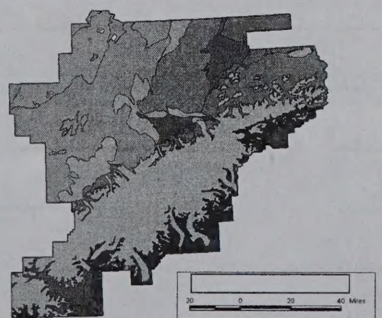
SOIL SURVEY FIELD DATA DATABASE

- Soil Survey Field Data Database (SSFDD)
  - 264 study sites, 791 transects, and 2200 stops investigated in six field seasons
  - Detailed soil and site descriptions for all stops
  - Digital photos of soils, vegetation, and landscapes coded
  - Complete plant species list, strata, and cover for all stops and tree data where applicable
  - GPS positions for all points

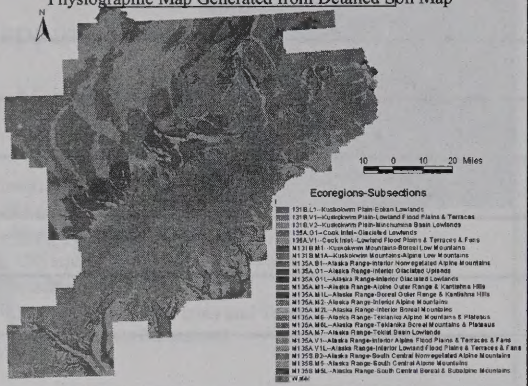


Physiographic Map (Subsections)

Draft map replaced by aggregation of detailed mapping

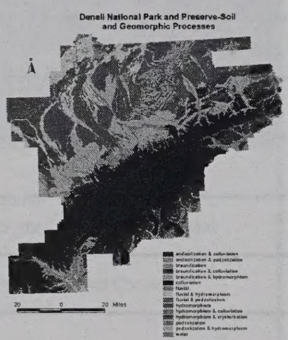


Physiographic Map Generated from Detailed Soil Map



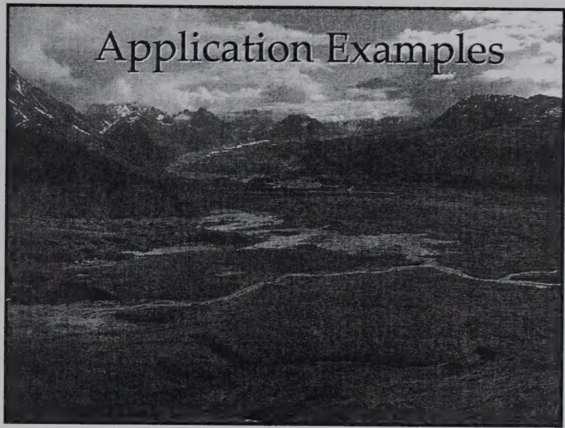
Evaluation of Tools

- 1:60,000 CIR Alaska High Altitude Photos (stereo) best tool
- GIS and GPS tools
  - Navigation and plot stops
  - Interim products
  - Correlation
  - Rule based applications
- SSFDD-Field database
  - 2200 complete pedons
  - Quick input and analysis
  - Ecological site reports linked to NASIS download
- Soil Temps (HOBOS)-new suborders (24 sites)



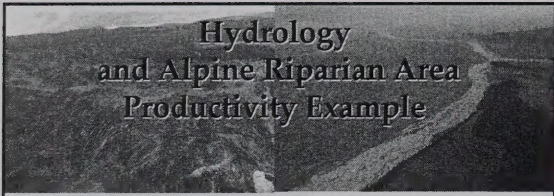
Evaluation of Tools

- Field Computers-Husky
  - Not well suited to low temps, field conditions, eye strain, etc.
- NASIS as applied to this project
  - Poorly suited to population from scratch
  - Duplicate component records stored
  - Dependency of data fields on other fields
  - "Glacially slow" network response time
  - Shift in responsibilities of project from science to data management
  - Powerful interpretive and reports tools

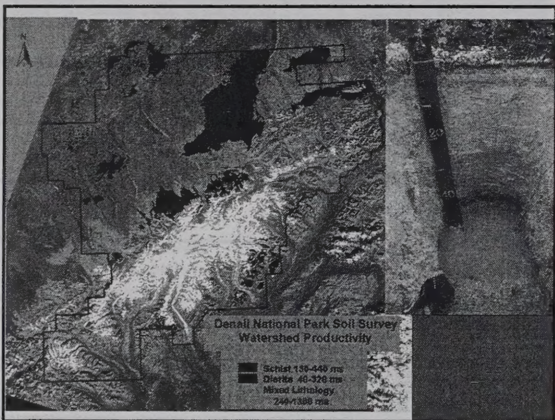


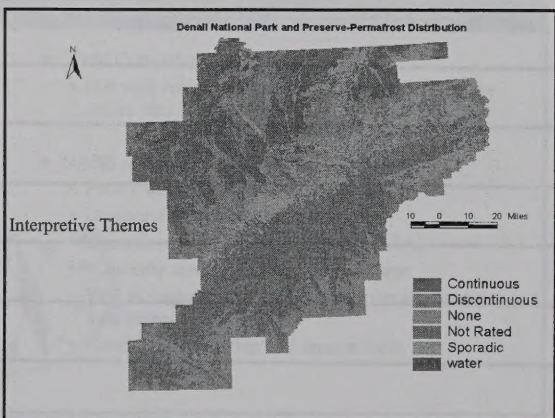
Tussocks and Fish Habitat Example

- Brown water systems-productive grayling habitats
- Associated with stream terraces with tussocks and permafrost
- High levels of organic carbon transport into riverine systems via surface water flow between tussocks



- Relation between soil mineralogy and riparian hydrology in alpine areas
- Electrical conductivity of water tables
  - Diorite soils 40-320 micro-siemens
  - Schist soils 130-440 ms
  - mixed lithology 240-1300 ms
    - free carbonates





Profile Development Index – Jennifer Harden, USGS

When you can't figure it out just take a nap

Introduction to Exercises

An Interagency Agreement entered into by the NPS and NRCS for mapping Crater Lake National Park identified specific "products" to be developed and delivered.

These "products" were addressed within the soil survey workplan, which required mapping concepts to be utilized to support field data collection, NASIS data population, soil manuscript development, and digital map finishing needs.

Crater Lake National Park Soil Survey Report

Review of the "delivered product"

Exercise Background

Crater Lake National park needed soils information (products) to support various issues the park was facing as part of the "DRAFT" Resource Management Plan

1. **Provide information on potential soil – landscape vulnerability issues that might arise by the Park's planned action to re-introduce fire into the ecosystem**
2. **Clarify soil – plant – landscape relationships, and address concepts of "soil productivity" to assist in various restoration projects**
3. **Needed soils information at not only a detailed level, but also at a general "park level", but still relative to the detailed product. ("Generalized soil map" vs. General soil map)**

Exercise 1

Provide information on potential soil – landscape vulnerability issues that might arise by the Park's planned action to re-introduce fire into the ecosystem

1. **Using the Crater Lake NP soil attribute database, use the report function within MS ACCESS to generate a Selected Soil Interpretation for 2 Soil Interpretations**

   FOR – Potential Erosion Hazard (Off Road/Off Trail)
   FOR – Potential Fire Damage Hazard

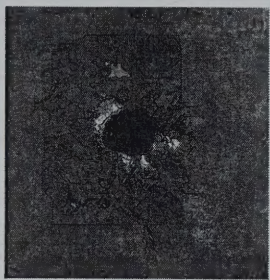
Introduction To Exercise 2 – Data Aggregation

"Need soils information at not only a detailed level, but also at a general "park level", but still relative to the detailed product." ("Generalized soil map" vs. General soil map)

1. **As part of the development of the Interagency Agreement and subsequent soil survey workplan, the soil survey crew was tasked to develop a soil - landscape - parent material – vegetation community model approach not only in the design of the detailed soil map unit legend, but to use this same concepts in the development of a general soil map, using the actual soil map unit delineations as the original source to perform the data aggregation on. The same concepts of the map unit description from the detailed map unit descriptions would also be used in the general soil map unit descriptions.**

Exercise 2 – Data Aggregation

Generalized Soil Map
Crater Lake National Park, Oregon



Exercise 2 – Data Aggregation

Use ArcView, and the Geospatial Processing Wizard to generalize the detailed soils data layer to pre-determined map units, creating a "generalized" soil map

Use the ArcView Geoprocessing Wizard, selecting the "Dissolve features based upon an attribute.

1. **Select theme to dissolve – *soils***
2. **Select an attribute to dissolve on – *Gen_soil***
3. **Select the output file - *GSM***

Exercise 3

Provide information on potential soil – landscape vulnerability issues that might arise by the Park's planned action to re-introduce fire into the ecosystem

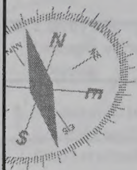
1. **Using the Crater Lake NP SSURGO products (geospatial and attribute databases) and Soil Data Viewer, develop a series of soil thematic maps based upon the following interpretations currently available use the report function within MS ACCESS to generate a Selected Soil Interpretation for 2 Soil Interpretations**

FOR – Potential Erosion Hazard (Off Road/Off Trail)
FOR – Potential Fire Damage Hazard

Wrap up and Summary

Query participants on issues regarding the identification and development of information products.

Ask how they might use this acquired skill/knowledge on the job to better meet customer needs.



Soil Survey of Denali National Park Area, Alaska

Draft Report

USDA United States Department of Agriculture

Natural Resources Conservation Service

In cooperation with the U.S. Department of Interior, National Park Service

Soil Survey of Denali National Park Area, Alaska

Draft Report

Soil Survey of Denali National Park Area, Alaska

Introduction

Denali National Park and Preserve includes approximately 2,452,400 hectares of land in Interior and South Central Alaska (see Figure 1). The park entrance area is about 378 kilometers north of Anchorage and approximately 193 kilometers south of Fairbanks along the George Parks Highway (Alaska Highway 3). Denali National Park, formerly known as Mount McKinley National Park, was established in 1917. The original 853,113 hectares, now designated as wilderness except for the access road corridor and entrance area, form the core of the park and preserve. In 1980, 1,058,925 hectares of new park and 540,113 hectares of preserve land were added under the Alaska National Interest Lands Conservation Act (ANILCA), and the name was changed to Denali National Park and Preserve. It is bounded primarily by state land, including Denali State Park on the south side.

This survey was a cooperative effort of the Natural Resources Conservation Service (NRCS), United States Department of Agriculture, and the National Park Service (NPS), United States Department of Interior and the University of Alaska Faribanks. NRCS was responsible for survey design and methodology, data collection and analysis, and survey products. Fieldwork was completed during the months of July, August, and September from 1997 through 2002. Soil names and descriptions were approved in 2003. Unless indicated otherwise, maps and supporting documentation in this report refer to conditions in the survey area in 2002.

Survey Purpose and Product Limitations

The primary purpose of the survey was to describe and map the soils of Denali National Park and Preserve. Area soils were mapped at a scale of 1:63,360 and detailed descriptions of map units, soil types, and Landtypes, including potential natural plant communities and major seral communities. As an aid to understanding the ecological aspects of the soil information, the detailed soil map was integrated into a multi-level ecological stratification of the area based on National Hierarchical Framework of Ecological Units (ECOMAP 1993). Subsection level units provided at a scale of 1:250,000 were made by aggregating the detailed soil mapping together into more generalized categories based on similar physiography and biome. Landtype Association level units of the hierarchy are synonymous with detailed soil map units mapped at a scale of 1:63,360. Higher levels in the system have been mapped and described as a part of Alaska statewide (Nowacki and Brock 1995) and national efforts (McNab and Avers 1994; Bailey et al. 1994). General maps and descriptions of park and preserve resources were created based on this approach. The classification and mapping hierarchy for Denali National Park and Preserve area is described in Appendix A of this report.

The scale of the map base imposes certain cartographic limitations in terms of the minimum size of individual delineations that can be made while maintaining map legibility and the maximum location accuracy of polygon boundaries that can be expected. On detailed soil maps compiled at 1:63,360 scale, polygon delineations of less than about one square centimeter, or about 15 hectares, results in a reduction in map legibility and have generally been avoided. Maximum location accuracy of polygon lines that can be expected and this mapping scale is about 15 meters. The Subsection map was compiled at 1:250,000 scale resulting in

a minimum legible delineation size of about 250 hectares. The process of aggregating the detailed soil mapping into the more generalized Subsection map resulted in the dissolution of many small polygons in order to maintain map legibility. These are important caveats when using digital spatial data in the Geographic Information System environment where scale is easily manipulated.

Other Products

In addition to standard soil survey products provided as part of the National Cooperative Soil Survey, several non-standard products are also included within this manuscript or provided to the National Park Service as supplemental data. A database including all 2,205 field stops with complete soil and vegetation descriptions and associated metadata is provided in Microsoft ACCESS format under separate cover. An ARCVIEW shapefile with the location of all field data stops is also provided under separate cover. Part of the ACCESS products is a database table titled “taggregateMAPUNIT” that includes a host of mapunit level interpretations. When joined to the digital mapping, this table may be used to general interpretive maps for a variety of resource themes including permafrost distribution, general potential vegetation, ECOMAP Sections and Subsections, and landforms, to mention a few. Several of these derivative products are represented as figures elsewhere within this document. Other products within this manuscript include photographs for each detailed map unit, soil taxonomic unit, and potential natural community and seral communities for each Landtype. Soil temperature graphs are provided for many of the soils described in the Soil Classification and Taxonomic Unit Descriptions section. Also included are oblique landscape diagrams showing typical soils and vegetation of the various regions of the Park and riverine illustrations displaying soils, parent materials, vegetation and hydrology of several riverine map units. All data, maps, orthophotography, and this report have been produced and maintained in a digital format. Electronic copies of this report, including plates and figures, map data, and metadata, can be obtained either through the NPS National Park Regional Office in Anchorage or the Research and Resource Preservation Division, Denali National Park. Soil and vegetation field data and composite data for soil map units can be obtained through the NRCS State Conservationist in Palmer, Alaska.

Survey Methods

The Natural Resources Conservation Service (NRCS) developed inventory objectives and procedures in conjunction with potential National Park Service (NPS) users and recorded these objectives in a memorandum of understanding.The mapping base selected for the detailed soil map was the Alaska High Altitude Photography (AHAP) and this was compiled to the USGS Alaska 1:63,360 Series Orthophotography, dated 1982. The draft ECOMAP Subsection map was compiled to the National Park Service-Denali National Park and Preserve Topographic map dated 1958 (revised 1986) at 1:250,000 scale.These resources were obtained from the NPS and the Bureau of Land Management (BLM).

Prior to fieldwork, a draft physiographic (ECOMAP Subsection) map was assembled for the entire park using relevant literature and other information on climate, geology, geomorphology, hydrology, and vegetation. Aerial photography and satellite imagery were used to estimate the distribution and extent of landforms and vegetation patterns. The draft Subsection map served as a planning tool for fieldwork and also provided an interim reference illustrating general soil-landform and soil-vegetation relationships of Park resources.

A geographic block of approximately 405,000 hectares was selected each year for mapping. Using the Alaska High Altitude Photography (AHAP) and a stereoscope, tentative polygons were delineated on mylar overlays to the aerial photography. Initial map unit assignments were made based on apparent landform and vegetation patterns. Representative areas were then selected for field evaluation and documentation of soil and vegetation conditions. These representative areas or “study sites” consisted of two to four different but contiguous map units that could be crossed and documented during a single field day. This approach minimize expenses and also helicopter activity in any one area of the Park while providing supporting documentation for mapping. Field documentation includes 264 study sites visited during six summers of fieldwork.

Soil and vegetation field data were collected by transecting tentative polygons within each study site. Observations made included major soil types and associated landforms, site properties, and plant communities. A transect consisted of one to several stops within an individual delineation on the map. The number of required stops was dependent on the complexity of the delineation. Corresponding soils and vegetation data and notes were linked using common transect and stop numbers. All transect and stop locations were recorded using a GPS for permanent record and later reference during map preparation and data analysis. Field documentation includes 791 transects and 2,204 stops documented during six summers of fieldwork. During the fieldwork draft maps were evaluated for accuracy of line placement and polygon assignments. Samples of some of the soils in the area were collected for laboratory analyses. Laboratory data, together with the observed soil characteristics and properties, were used to provide baseline information of soil properties.

Following each field season, field data were entered into the Alaska Soil Survey Field Database (SSFDD) for data management and analysis. A complete reevaluation of draft field mapping using a stereoscope and referencing documented field data was also completed at this time. Polygons were then transferred to overlays of the orthophotography, scanned, and digitized. Interim products were distributed to the National Park Service. Results of data analysis were entered into the standard NRCS National Soils Information System (NASIS) database. Finally, the ECOMAP Subsection map was regenerated from the detailed soils map.

General Nature of the Survey Area

Physiography and Major Soil Orders

Straddling the Alaska Range, Denali National Park is dominated by the Denali massif, and its barren peaks of ice and rock that take up almost one-third of the park's total area. Alpine glacial plains skirt the mountains along the parks north side gradually giving way to lowland forested plains and hills; a land underlain by permafrost and modified by wildfire. South of the Alaska Range crest is a seldom-visited area of steep mountains and broad river valleys, an area of significantly more moderate climate influenced by the Gulf of Alaska 160 kilometers to the south. This mountainous terrain is shrouded in clouds, rain, and snow during much of the year and this abundant moisture supports herbaceous meadows and alder scrubs that cloak the lower mountain slopes. Only a small area of the South Central lowland forests is included within the park's southern border.

Denali National Park and Preserve includes five major physiographic Sections (Nowacki and Brock, 1995). These are the Alaska Mountains, South Central Mountains, Cook Inlet Lowlands, Yukon-Kuskokwim Bottomlands and Kuskokwim Mountains (see Figure 2). The most extensive single physiographic feature, the Alaska Range, includes both the Alaska Mountains and South Central Mountains Sections (see Figure 3) and occupies about 60 percent of the Park. This mountain range, dominated by 6,194 meter high Mt. McKinley, forms a southwest to northeast trending arc across central Alaska and is the focal point of Denali National Park. Above about 1,500 meters elevation, the range is steep and extensively faulted, consisting of a wide range of rock types including shale, andesite, schist, diorite, conglomerate, and limestone. Landforms include precipitous barren alpine mountains capped by permanent snowfields and glaciers flanked by talus slopes and cirque valleys (see Plate 1).

The Alaska Mountains Section at elevations below about 1,500 meters consist of steep alpine talus slopes, locally flanked by glacial deposits on more gentle slopes (see Plate 2). Skirting the steep mountains, and much more subdued in relief, are rounded low mountains, plateaus, glacial plains, and hills (see Plates 3, 4, and 5). Dissecting all landscapes of each Section are braided glacial-fed rivers and clear water streams with their adjacent flood plains, alluvial fans, and terraces. Soil materials are of three main types: 1) Gravelly colluvium of variable lithology and drift in the mountains; 2) Drift in broad valleys and lower mountain slopes and extending outwards from the mountains as aprons of glacial plains and hills; and 3) Loamy and gravelly alluvium found on flood plains and terraces. Figures 4 and 5 provides two satellite images showing typical landscapes, soils, and vegetation of the Alaska Mountains section. A unique periglacial feature on landforms of this Section is "patterned ground"; the regular surface patterns associated with intense frost action. These

features include steps (see Plate 6), stripes (see Plate 7), circles (see Plate 8), gelifluction lobes (see Plate 9) and earth hummocks (see Plate 10). Polygonal ground (Plate 11) is an extensive pattern ground feature associated with massive ground ice features and permafrost in the Toklat Basin area. Major soil orders include Inceptisols in steep mountains (see Plate 12), Spodosols on coarse texture alluvium and glacial deposits (see Plate 13), Gelisols on more gently sloping loamy drift and alluvial deposits (see Plate 14), and Entisols on flood plains (see Plate 15).

The South Central Mountains Section at elevations below about 1,500 meters includes steep alpine talus slopes consisting of an admixture of gravelly colluvium and volcanic ash. Volcanic ash materials originate from the many volcanoes within the Alaska Range and Aleutian Range to the west. Lower slopes consist of a mantle of volcanic ash over glacial drift deposits. Figure 6 provides a satellite image with typical landscapes, soils, and vegetation of the South Central Mountains Section. Periglacial landforms common to more northerly areas of the Park and Preserve are rarely observed in the South Central Mountains Section (see Plate 16). Major soil orders include Andisols (see Plate 17) and Inceptisols on steep mountains (see Plate 18), with Spodosols (see Plate 19) and Andisols on lower slopes.

The Yukon-Kuskokwim Bottomlands, located in the northwestern part of the Park, is the second most extensive physiographic feature in Denali, consisting of an expansive lowland area of plains, hills, relict sand dunes, bogs, fens, and ponds (see Plate 20). Beyond the limits of ice during the Pleistocene glaciations, this was part of a larger area often referred to as "Beringia," which included much of Interior and Western Alaska, the Bering Land Bridge and Eastern Siberia. This Section represents the largest contiguous area of permafrost-affected soils, as well as wetlands, within Denali National Park and Preserve. Soil materials are primarily loess and eolian sand on hills and plains, and stratified loamy textured alluvium as well as gravelly alluvium on flood plains. Major soil orders include Gelisols (see Plate 21) and Histosols (see Plate 22) on uplands and Entisols (see Plate 23) on flood plains.

Scattered throughout this lowland are the isolated low mountains of the Kuskokwim Mountains Section. This physiographic area is minor in extent, occupying less than five percent of the Park. Rounded low mountains cored with schist and mantled with mica-rich loess dominate the topography of this Section. Lower slopes have taiga or hardwood forest vegetation with occasional high summits of alpine scrub and tussock (see Plate 24). Major soil orders include Gelisols (see Plate 21) and Inceptisols (see Plate 25).

The Cook Inlet Lowlands Section, though extensive in South Central Alaska, occupies less than 5 percent of Denali National Park. Landforms in uplands include glacial plains and hills with mixed forest interspersed with bogs and fens (see Plate 26). Braided flood plains with mixed conifer-hardwood and hardwood forests, scrub vegetation, and fens occupy valley bottoms along major rivers of the area. Soil materials include volcanic ash over glacial drift in uplands, and loamy and gravelly alluvium on flood plains. Major soil orders include Spodosols (see Plate 19), Andisols (see Plate 27), and Histosols (see Plate 28) in uplands and Entisols (see Plate 15) on flood plains.

Climate

Denali Park is divided into two sub-regional climates. Areas lying north of the hydrographic divide of the Alaska Range are considered sub-arctic continental, often referred to as Interior, and those lying to the south are transitional maritime-continental, often referred to as South Central (see Figure 7). These two sub-regional climates differ not only in terms of statistical measurements of temperature and precipitation, but also in the types of vegetation and landscape features that are unique to each.

Based on climatic summaries from the Western Regional Climate Center, the sub-arctic continental climate characteristic to Interior Alaska consists of long cold winters and short warm summers. Mean minimum January air temperatures at Minchumina along the northwest border of the park are -24.8 degrees C with mean maximum July temperature of 22 degrees C. Total precipitation is relatively low, totalling 3,254 mm. The transitional maritime-continental climate of South Central has long cool winters and short mild summers. Mean minimum January air temperatures at Talkeetna, outside the southern border of the park, are -16.8 degrees C with mean maximum July temperature of 19.9 degrees C. Average precipitation at Talkeetna is over double that of the Minchumina station, weighing in at 7,087 mm due to the more significant marine influence (see Tables 1, 2, and 3).

Vegetation of the South Central climate zone is markedly different from the Alaska Mountains sections, as discussed below. Many species that are dominant on the south side are found only in small populations north of the range. Some species are almost completely restricted to the South Central climate, and may be used as indicators of it. These plants occur only rarely on the north side, primarily in valleys positioned along the transition between the two climates. A list and description of these indicator species is provided in Appendix C.

Geologic Features

Denali National Park and Preserve consists of three rock provinces that occupy or extend in East-West bands through the park, and generally represent the oldest to youngest rocks from north to south (Harris et al. 1997). The largest province, the Yukon-Tanana Terrane, takes up most of the northern half of the park, where the oldest, most highly altered marine and volcanic rocks underlie smaller pods or veneers of Quaternary and Tertiary sediments. These rock groups are associated with the northern half of the Alaska Mountains Section and all of the Kuskokwim Mountains Section (see Plate 29). A smaller group of slightly younger, and slightly less altered marine sediments (see Plate 30), the Pingston/McKinley Terranes can be found along the Alaska Range crest, where in places, they are pierced and/or covered by much younger granitic and volcanic rocks. This terrane corresponds to the southern part of the Alaska Mountains Section. Younger still is the Kahiltna Terrane that includes the majority of the rocks in the southern third of the park, where the great Mount McKinley and other mountains consisting of plutonic rocks (see Plate 31) have intruded into shallow marine sediments. The rocks of the Kahiltna Terrane are included within the South Central Mountains Section.

These rock provinces are separated by the Denali fault system, a series of major crustal fractures that arc through Denali Park and the southern third of Alaska. This fault extends from Canada, entering Alaska in a northwesterly trending arc then turning southwesterly out into Bristol Bay and the Bering Sea. A portion of the Hines Creek strand of the fault system parallels the park road for the first 48 kilometers of its course from the park entrance to the Teklanika River area. It separates the oldest “Yukon-Tanana” terrane from the Mesozoic “Pingston/McKinley” terranes, and bisects portions of the Paleozoic “Farewell” terrane. The east-west trending McKinley strand of the fault system crosses the Parks Highway between Fairbanks and Anchorage just north of the town of Cantwell. The fault continues westerly into the park on the south side of the Alaska Range some 80 kilometers to Anderson Pass, where it then crosses the range to the north side to continue to arc around Mt McKinley and on to the southwestern regions of the park and beyond. The McKinley strand separates the Farewell terrane from the Late Mesozoic-Early Tertiary “Kahiltna” terrane in the eastern portion of the park, while it splits the Farewell Terrane in the western parts of the park.

Permafrost Distribution and Wildfire

Permafrost, or perennially frozen ground, is common throughout the Interior climatic zone and generally absent in the South Central climatic zone. Within the Alaska Mountains, Yukon-Kuskokwim Plain, and Kuskokwim Mountains Sections, permafrost is extensive on loamy textured soils within the Boreal biome and is only occasionally observed in gravelly alpine soils. Commonly, landscapes underlain by permafrost have open dwarf spruce forest or woodland in which trees are tipped in various directions due to frost heave (see Plate 32). The depth at which permafrost occurs, as well as ice content, vary widely. In many places, permafrost consists of small ice crystals, lenses and seams disseminated throughout the soil (see Plate 21) . Elsewhere, permafrost consists of massive ice features several meters thick (see Plate 33). In most areas, a perched water table and saturated conditions are common above the permafrost during the summer due to restricted drainage. The most extensive contiguous areas of soils with permafrost are within the Yukon-Kuskokwim Plain Section and the Toklat Basin Subsection of the Alaska Mountains Section. A map illustrating the distribution of permafrost within Denali is provided in Figure 8.

Wildfires, which are common in the boreal and lowland Subsections of the Park, can have a profound impact on the distribution and depth of permafrost. Plate 34 illustrates a recent fire and the blackening of the surface in the Kantishna Hills area. Plate 35 shows a burn scar from a past burn along the lower McKinley River. The short-term impact following most wildfires is warming of the permafrost and an increase in the thickness of the active layer, the surface layer that thaws during summer. As permafrost thaws, a large

volume of water is liberated and either accumulates in depressions or runs off through surface or subsurface drainage outlets. Differential subsidence of the soil surface and slumping on steeper slopes can occur, depending on the ice content of the permafrost and the rate of thawing (see Plate 36). Gradually, in the absence of additional fires or disturbances, the moss-organic layer reestablishes and permafrost level returns to the pre-fire condition (Foote 1976; Viereck 1973). Plant community dynamics associated with fire are described in more detail in Appendix C.

Vegetation

General patterns of vegetation in the study area are the result of two major influences: the elevation gradient of the Alaska Range, and the different climactic regions north and south of the range. Much of the Park and Preserve is above tree line, and almost one-sixth is non-vegetated ice and rocky mountain slopes. In the vegetated zone, harsh conditions at high elevations limit plant communities to dwarf scrubs, and herbaceous meadows in nivation hollows. Medium or tall scrubs are found lower down the slopes, and these grade into forests or woodlands on well-drained substrates at lower elevations. Poor drainage at all elevations, due to glacial drift or permafrost, limits productivity. In lowlands, wet woodlands, scrubs, and herbaceous communities are found in a mosaic of fens, bogs, marshes and muskegs. The General Potential Vegetation map (see Figure 9) shows the distribution of the major vegetation types found in the Park and Preserve. A more detailed description of the vegetation is found in Appendix C.

North of the range in the drier, Interior climate, the vegetation patterns of the Yukon-Kuskokwim Bottomlands and Kuskokwim Mountains Sections are strongly influenced by permafrost and periodically modified by wildfire. Dwarf needleleaf permafrost woodland is dominated by black spruce (*Picea mariana*), which is often less than 5 meters tall (see Plate 37) but may be over a century old. Numerous ponds, bogs and fens dot this extensive area. Paper birch (*Betula neoalaskana*) forest, sometimes mixed with white spruce (*Picea glauca*) (see Plate 38) and with an under story of green alder (*Alnus viridis* ssp. *crispa*), dominates warm slopes of the low Kuskokwim Mountains. Well-drained floodplains associated with major rivers support narrow, productive forests of white spruce and poplar (*Populus balsamifera* ssp. *balsamifera*), with associated communities of alder (*Alnus* spp.) and willow (*Salix* spp.) scrub, but they are of very limited extent. Wet terraces and ridge tops are covered by tussock cottongrass (*Eriophorum brachyantherum* and *E. vaginatum*) (see Plate 10), a mixture of low ericaceous shrubs, and Bigelow sedge (*Carex bigelowii*), especially in the Toklat Basin.

Mountain vegetation of the Alaska Mountains Section is dominated by white mountain avens (*Dryas octopetala*) -dwarf ericaceous shrub scrubs (see Plate 39), which grade into medium-sized scrubs dominated by shrub birch and ericaceous shrubs such as blueberry (*Vaccinium uliginosum*), Labrador tea (*Ledum palustre* ssp. *decumbens* and *L. groenlandicum*) and crowberry (*Empetrum hermaphroditum*). These scrubs sometimes have high percentages of sedge and other herbaceous vegetation on cooler, more northerly aspects. Warmer low slopes, especially in the Kantishna Hills and Park Headquarters areas, support white spruce/mixed scrub woodlands.

South of the Alaska Range summit, the South Central climate is wetter, milder, and less influenced by fire. The plant communities there are quite different. Mountain vegetation of the South Central Mountains Section is similar to the north side, but is much more ericaceous, with Steller cassiope (*Cassiope stelleriana*) (see Plate 40) and crowberry, as well as partridge foot (*Luetkea pectinata*), being the most important species. Barclay willow (*Salix barclayi*) (see Plate 41) forms a mosaic with medium-sized herbaceous meadows between the dwarf alpine communities and the tall Sitka alder (*Alnus sinuata*)/tall herbaceous meadow mosaics of the lower slopes. Forested communities of paper birch, some mixed with white spruce, are limited to lower slopes. The well-drained river terraces of the Cook Inlet Lowlands are of very limited extent, and are found mostly in the east and west forks of the Yentna River. They support riparian forests of poplar and sometimes black cottonwood (*Populus balsamifera* ssp. *trichocarpa*) (see Plate 42), with associated scrub communities of alder and willow. Poorly drained lowlands, underlain by glacial drift, support a mosaic of alder scrubs and wet herbaceous meadows.

Wildlife

There are 37 mammal species recorded in the park and preserve. Dall sheep inhabit the high mountains throughout the two Alaska Mountains and South Central Mountains Sections. Caribou migrate great distances, mainly within the Alaska Mountains Sections from their calving grounds south of the Alaska Range and northwest of Mount McKinley to their winter range in the northern reaches of the park and preserve. Wolves range throughout the Park and often follow the migrating caribou herds. Moose can be found in all reaches of the park, though they are rarely seen in large numbers. Both black and grizzly bears are numerous and omnivorous, eating plant roots, leaves and berries, ground squirrels, moose or caribou calves, and occasionally carrion. Smaller mammals common to this northern environment include fox, weasel, wolverine, lynx, marten, snowshoe hare, hoary marmot, red squirrel, ground squirrel, pika, porcupine, beaver, and several species of shrews, voles and lemmings.

Bird life is varied at Denali with 156 species of birds recorded. Most birds migrate long distances between their nesting grounds here in the park and their wintering areas. Wheatears winter in Africa; arctic terns in the waters around Antarctica and southern South America; jaegers take to life at sea in the southern oceans. Among the widespread, year-round residents of the park are the raven, willow ptarmigan, magpie, and gray jay. Birds occupying more specific habitats in the park include rock and white-tailed ptarmigan, Lapland longspur and Golden eagle, which are found primarily in the alpine areas of the Alaska Mountains Section. Spruce grouse and varied thrush inhabit the forested areas

Resource Descriptions

Ecosystem Classification Method Used to Map Soil Resources

The National Ecological Unit Hierarchy or ECOMAP method was used in this project. This hierarchy provides a system for classifying and mapping areas of the earth based on associations of ecological factors at different geographic scales (Cleland et al. 1997). The eight levels of the hierarchy, beginning with the highest and most general level, are Domain, Division, Province, Section, Subsection, Landtype Association, Landtype, and Landtype Phase. Higher levels in the system have been mapped and described as a part of Alaska statewide (Nowacki and Brock 1995) and national efforts (McNab and Avers 1994; Bailey et al. 1994). A description of this hierarchy as applied to the Denali National Park are included in Appendix A and a list of the hierarchy of units for the Section, Subsection, and Landtype Association levels are provided in Table 4. This section provides specific definitions and resource information for the lower five levels of the hierarchy. In addition, soil taxonomic units are also described in this section.

ECOMAP-Sections

This part includes a map of the five ECOMAP Sections of the ecological unit hierarchy (ECOMAP 1993) found within Denali National Park (Figure 2) and a brief description of each Section modified from McNab and Avers (1994). Sections are subdivisions of Provinces and each Section is restricted to a single Province. Provinces and higher levels in the system were not described as a part of this document but are described by McNab and Avers (1994). See Appendix A for a complete description of the ecological unit hierarchy.

Section 131B—Yukon-Kuskokwim Bottomlands

Setting. This Section represents a collection of flat bottomlands along the larger rivers of interior Alaska. Although nearly level, broad valleys and basins are typical, some low rolling hills do occur. Riparian features, such as meandering streams and side sloughs, are prevalent. Oxbow, and thaw lakes are abundant. Elevation generally ranges from 120 to 650 m. Alluvial fan and basin fill of late Tertiary and Quaternary age are most common. The dominant soils in uplands have shallow permafrost and aquic moisture regimes and are classified within the Orthel and Turbel Suborders of Gelisols. Common soils on flood plains include the Orthent Suborder of Entisols. Most soils were formed in loess in uplands and alluvial materials on flood plains and terraces. Dominant vegetation communities span a moisture gradient from mesic to hydric and include spruce (*Picea spp.*)-poplar (*Populus spp.*) forests, open black spruce (*Picea mariana*) forests, flood plain thickets of willow (*Salix spp.*) and alder (*Alnus spp.*) scrub, and sedge wet meadow.

Climate. Average annual precipitation ranges from 250 to 650 mm. Average annual temperature ranges from -6 to -1 degrees C. The growing season is approximately from May 15 to September 10. The average freeze-free period is 70 to 120 days.

Disturbance Regimes. Wildfire is a very common event, averaging about 2,260 hectares in size. A high frequency of lightning storms, coupled with prevailing warm and dry summers, promote fire occurrence. River flooding is frequent, particularly in the spring.

Land Use. Primarily interior settlements and agriculture occur in this Section. Subsistence and recreational hunting and fishing are popular.

Cultural Ecology. Residents are mainly Koyukon, Tanana, and Kuskokwim Athabaskans.

Section M131B—Kuskokwim Mountains

Setting. The Kuskokwim Mountains are northeast-trending ridges having rounded to flat summits and broad, gentle slopes. Deep narrow valleys are prevalent. Elevation ranges from 170 to 1,350 m. This Section consists of deep ocean floor and continental fragments of the Tozitna, Ruby, Innoko, and Nixon Fork terranes. These are tightly folded Paleozoic and earlier rocks, some of which have been metamorphosed. The dominant soils are classified within the Orthel and Turbel Suborders of the Gelisols and the Cryept Suborder of the Inceptisol. Most soils are formed in loess and colluvium. Open black spruce (*Picea mariana*) forests are abundant. Alpine vegetation of sedges and shrubs cover most hills and ridges. White spruce (*Picea glauca*)-paper birch (*Betula neoalaskensis*) communities are also common.

Climate. Average annual precipitation ranges from 300 to 560 mm. Average annual temperature ranges from -6 to -2 degrees C. The growing season lasts approximately from May 15 to September 10. The average freeze-free period is 90 to 110 days.

Disturbance Regimes. Wildfires are frequent events.

Land Use. Subsistence and recreational hunting and fishing are the main human uses. Mining was formerly important.

Cultural Ecology. Koyukon, Holikachuk, and Ingalik Athabaskans reside in this Section.

Section 135A—Cook Inlet Lowlands

Setting. A level to rolling surface derived mainly through glacial events with major landforms including glacial plains, hills, and outwash plains as well as flood plains. Elevation ranges from sea level to 1,000 m. The dominant soils include Cryand, Aquand Suborders of Andisols, the Cryod Suborder of Spodosols, and the Saprist and Hemist Suborders of Histosols. Soils are formed primarily in volcanic ash, glacial drift, and organic materials. Lowland black spruce (*Picea Mariana*) forests are abundant. Bottomland spruce (*Picea spp.*)-poplar (*Populus spp.*) forests are adjacent to larger river drainages, along with thickets of alder (*Alnus spp.*) and willow (*Salix spp.*) scrub.

Climate. Average annual precipitation ranges from 300 to 2,200 mm. Average annual temperature ranges from -2 to 3 degrees C. The growing season extends from approximately May 10 to September 30. Average freeze-free period is 110 to 150 days. This Section is generally free of permafrost.

Disturbance Regimes. Wildfire occurrence is low.

Land Use. This Section is heavily populated and substantially affected by agriculture, urban development, petroleum extraction, and human recreation.

Cultural Ecology. Historically occupied by Tanaina Athabaskans, a variety of cultures now reside in this heavily developed Section.

Section M135A—Alaska Mountains

Setting. This Section consists of steep, rugged mountain ridges separated by broad valleys. Elevation ranges from 200 m in valleys to greater than 6,000 m on mountain peaks. The tallest peak in North America, Mount McKinley about 6,200 m, lies within this Section. The Section comprises fragments of deep ocean floor rock, as well as continental fragments of Peninsular, Kahiltna, and Wrangellia terranes. These are early Mesozoic to Cenozoic assemblages with very complex morphology. The dominant soils are classified within the Gelept Suborder of Inceptisols on mountains with the less common Orthent Suborder of Entisols on flood plains. Soils are formed primarily in colluvium with smaller areas of alluvium on flood plains. About two-thirds of the area has no soil. A substantial portion of the area is barren of vegetation. Where vegetation exists, alpine communities of dwarf scrub types. Spruce (*Picea spp.*) woodlands are common at lower elevations and riparian spruce-hardwood forests occur infrequently at low elevations in valley bottoms.

Climate. Average annual precipitation ranges from 250 to 2,950 mm. Average annual temperature ranges from -22 to -1 degrees C. Freezing conditions may occur year around.

Disturbance Regimes. Occurrence of wildfire is high in forested valleys and lower mountain slopes and low in alpine areas. Snow avalanches are frequent in the winter.

Land Use. Human use of the area is minimal, mainly consisting of hunting and fishing.
Cultural Ecology. Tanaina and Ahtna Athabaskans historically roamed this Section.

Section M135S—South Central Mountains

Setting. This Section consists of steep, rugged mountain ridges separated by broad valleys. Elevation ranges from 200 m in valleys to greater than 6,000 m on mountain peaks. The Section comprises fragments of deep ocean floor rock, as well as continental fragments of Peninsular, Kahiltna, and Wrangellia terranes. These are early Mesozoic to Cenozoic assemblages with very complex morphology. The dominant soils are classified within the Cryept Suborder of Inceptisols and Cryand Suborder of Andisols. Soils are formed primarily in colluvium and volcanic ash. About two-thirds of the area has no soil. A substantial portion of the area is barren of vegetation. Moderately extensive areas of subalpine alder scrub communites are found at lower elevation with higher areas consisting of alpine communities of dwarf scrub types. Spruce (*Picea spp.*) woodlands are common at lower elevations and riparian spruce-hardwood forests occur infrequently at low elevations in valley bottoms.

Climate. Average annual precipitation ranges from 500 to 3,450 mm. Average annual temperature ranges from -23 to -1 degrees C. Freezing conditions may occur year around. Permafrost is generally absent in this section.

Disturbance Regimes. Occurrence of wildfire is low and snow avalanches are frequent in the winter.

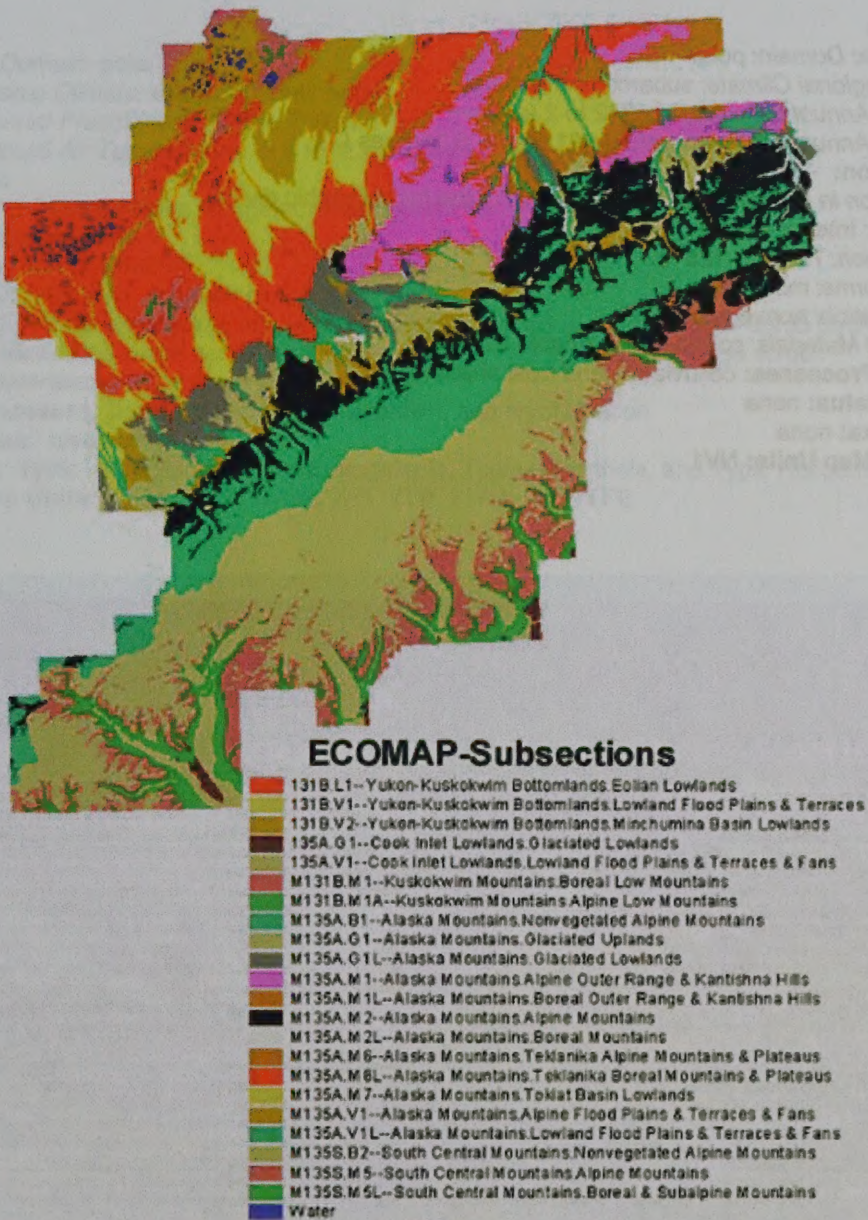
Land Use. Human use of the area is minimal, mainly consisting of hunting and fishing.

Cultural Ecology. Tanaina and Ahtna Athabaskans historically roamed this Section.

ECOMAP-Subsections (physiographic-biome map).

This part includes a brief description of each Subsection of the ecological unit hierarchy (ECOMAP 1993). Subsections are subdivisions of Sections. Each Subsection is restricted to a single Section. Subsections are smaller areas within Sections with similar surficial geology, lithology, geomorphic process, soil groups, subregional climate, and potential natural communities. Subsection boundaries usually correspond with discrete changes in geomorphology. Names of Subsections are usually derived from geologic features such as Toklat Basin or Kantishna Hills as well as the dominant biome. See Appendix A for a complete description of the ecological unit hierarchy. See Soil Formation for a definition of each geomorphic and pedogenic process mentioned in the descriptions. The Subsection map (Figure 10) was compiled at 1:250,000 scale.

Figure 10. ECOMAP Subsections Map



M135A.B1—Alaska Mountains.Nonvegetated Alpine Mountains Subsection

Climatic Data:
Climatic Domain: polar
Sub-regional Climate: subarctic continental
Mean Annual Precipitation: 742 to 2,939 mm
Mean Annual Air Temperature: -21.6 to -5.6 degrees C
Site Description:
Location in Denali: Alaska Range north of the hydrographic divide
Biome: Interior alpine
Elevation: 785 to 6,125 m
Landforms: mountains
Vegetation: nonvegetated
Parent Materials: colluvium of variable lithology
Geomorphic Processes: colluviation and frost shatter
Permafrost Status: none
Major Soil Taxa: none
Detailed Soil Map Units: NV1

M135A.G1—Alaska Mountains.Glaciated Uplands Subsection

Climatic Data:
Climatic Domain: polar
Sub-regional Climate: subarctic continental
Mean Annual Precipitation: 528 to 758 mm
Mean Annual Air Temperature: -3.5 to -2.4 degrees C
Site Description:
Location in Denali: Alaska Range northern footslopes
Biome: Interior alpine
Elevation: 304 to 1,536 m
Landforms: till plains, outwash plains, and hills
General Potential Vegetation: Interior-shrub birch-ericaceous scrub, Interior-shrub birch/sedge scrub and ericaceous dwarf scrub, and Interior-tussock and shrub birch/sedge scrub
Parent Materials: thin mantle of loess over drift
Geomorphic Processes: podzolization, hydromorphism, and cryoturbation
Permafrost Status: discontinuous
Major Soil Taxa: Typic Haplogelods, Typic Eutrogelepts, Typic Historthels, and Typic Histoturbels
Detailed Soil Map Units: 7FGA, 7NG, 7NG2, 7P1, 7TP, 7TP2, and 7TP8

M135A.G1L—Alaska Mountains.Glaciated Lowlands Subsection

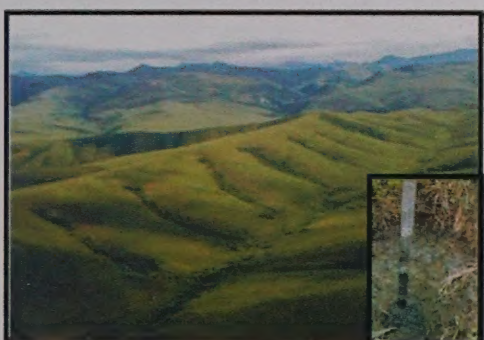
Climatic Data:
Climatic Domain: polar
Sub-regional Climate: subarctic continental
Mean Annual Precipitation: 506 to 732 mm
Mean Annual Air Temperature: -3.2 to -2.5 degrees C
Site Description:
Location in Denali: east central, central, and west central
Biome: Interior boreal
Elevation: 445 to 982 m
Landforms: till plains, outwash plains, and hills
General Potential Vegetation: Interior-white spruce/mixed scrub woodland and Interior-dwarf needleleaf permafrost woodland
Parent Materials: thin mantle of loess over drift
Geomorphic Processes: podzolization and hydromorphism
Permafrost Status: discontinuous
Major Soil Taxa: Typic Historthels and Typic Haplogelods
Detailed Soil Map Units: 7ES, 7P2, 7P4, 7P6, 7TP3, 7TP4, and 7TP5

Figure 4. Typical Landscapes, Vegetation and Soils of Northeastern Denali Park

Landform and Location: Mountains, Upper Sanctuary River
Landtype: Gravelly mountains, high elevation
PNC: White mountain avens-mixed ericaceous shrub dwarf alpine scrub
Soils: Alpine-dwarf scrub dark gravelly colluvial slopes

Landform and Location: Plains, Lower Toklat Basin
Landtype: Peat mounds
PNC: Cloudberry/sphagnum moss wet meadow
Soils: Alpine-scrub organic mounds, frozen

Landform and Location: Flood plains, Lower Teklanika River
Landtype: Gravelly flood plains
PNC: White spruce-poplar/soapberry forest
Soils: Boreal-riparian scrub gravelly flood plains, moderately wet



Landform and Location: Low mountains, Upper Sushana River
Landtype: Gravelly frozen slopes
PNC: Shrub birch-mixed ericaceous shrub/sedge scrub
Soils: Alpine-scrub-sedge gravelly slopes, frozen

Landform and Location: Plateaus and mountains, Northeast Corner of Park
Landtype: Loamy frozen slopes
Late serial fire community of white spruce-black spruce/shrub birch woodland
Soils: Boreal-taiga gravelly slopes, frozen

Product Development Exercises

Exercise 1

[illegible]

[illegible]

[illegible]

[illegible]

Procedures

[illegible]

[illegible]

Product Development Exercises

Exercise 1

This exercise focuses on the use of the SSURGO MS Access Download for Crater Lake National Park to develop custom reports to support issues regarding the introduction of fire into the ecosystem, and the potential impacts on their valuable soil resources.

Objectives: Allow participants to utilize the SSURGO MS Access download from the National Soils Information System (NASIS) to generate products to meet user needs. Participants will be working with a "CUSTOMIZED" SSURGO ACCESS download generated from the SSURGO Template developed at the USDA-NRCS MO -1 Office, Portland, OR .

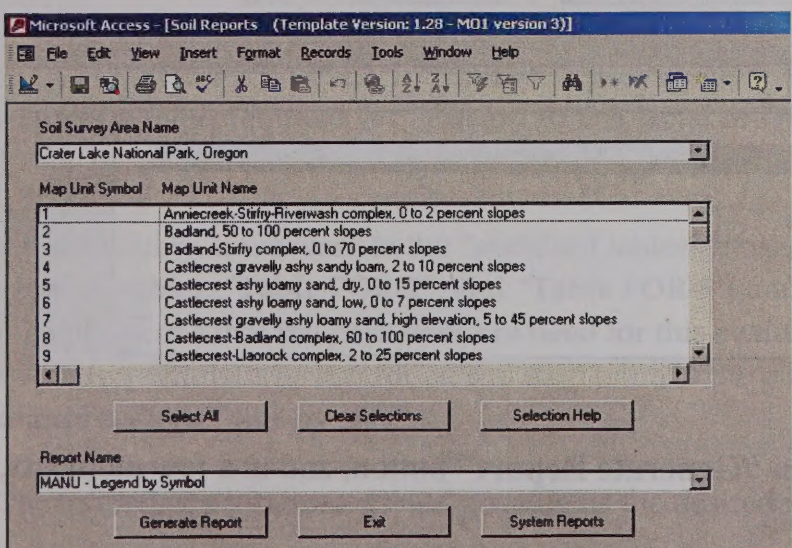
Several local reports have been developed for the MO-1 SSURGO Access templates. This exercise will focus on the use of the following local report

Map Unit Description – MO1: Designed to produce an abbreviated semi-tabular map unit description. The intent is to serve as a partial replacement for the single-phase interpretation sheets that were available when SOILS-5 forms were used for soils data.

Procedures:

1. On your computer desktop, click on "My Computer", and navigate to the following path: **C:\Adv_Tech_Soils\Data\Products\GIS\SOIL_DB**

2. Double click on the file **"soils"**, and this will open up the MS Access database, and you should see the following;

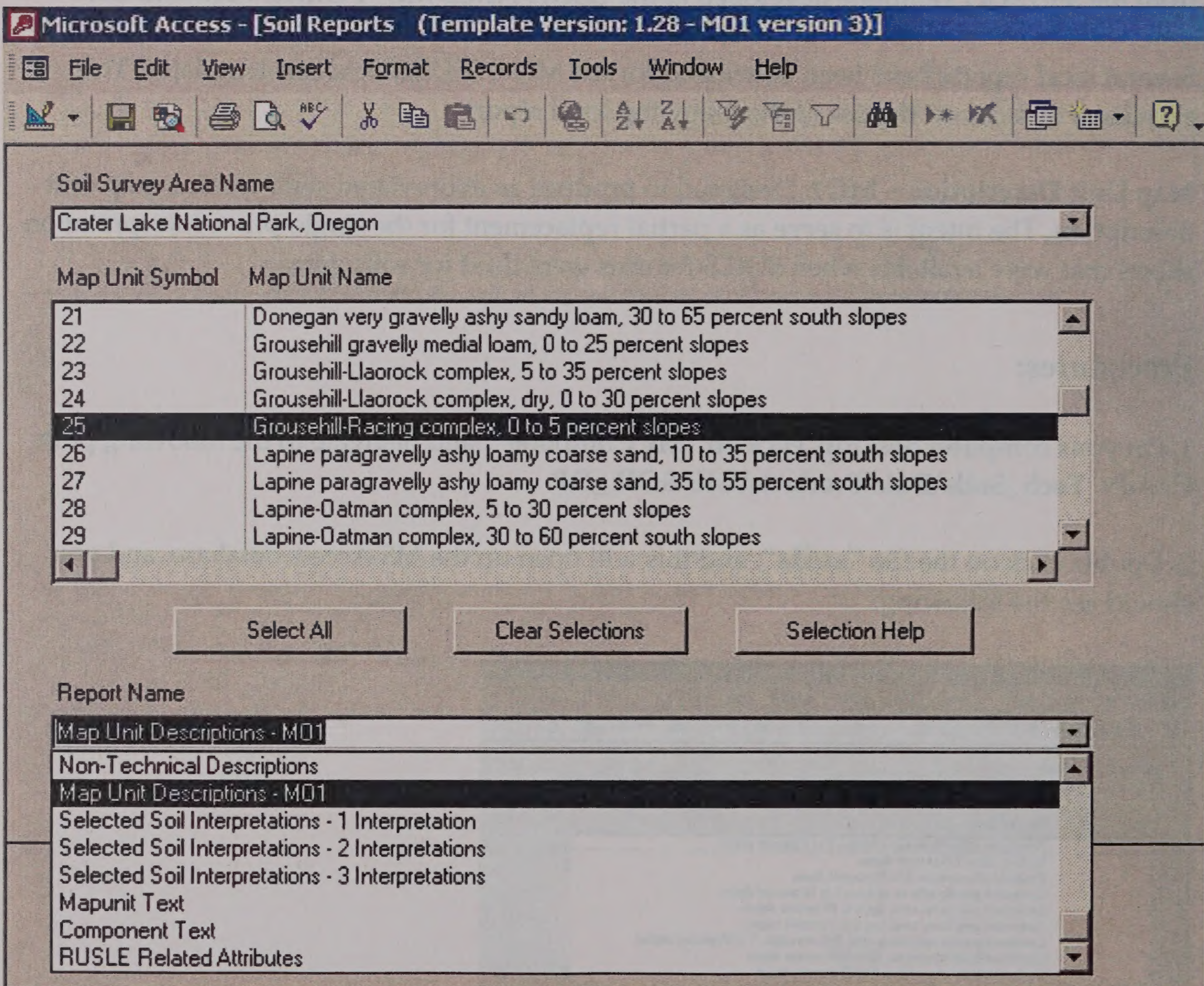


3. What we want to do now is look at the option to create a report containing the Soil Map Unit Descriptions for Crater Lake National Park.. For time sake, we will focus on generating a map unit description for only one map unit, **25-Grousehill-Racing complex, 0 to 5 percent slopes**

4. To do this, under the column "**Map Unit Symbol/Map Unit Name**", navigate down until you find map unit symbol "**25**", and select it.

5. Under the "Report Name" column, navigate down until you find the report **"Map Unit Descriptions – MO-1"**, and select it.

You should see the following;



6. After confirming these selections, hit the **"Generate Report"** button, and in a few moments, a report will appear

You should get a report which resembles the following;

Mapunit Descriptions

Crater Lake National Park, Oregon

---

25 - Grousehill-Racing complex, 0 to 5 percent slopes

Mean annual precipitation: 50 to 70 inches
Mean annual temperature: 38 to 42 degrees F
Frost-free period: 10 to 50 days
Farmland class: Not prime farm land

Grousehill and similar soils

Extent: about 50 percent of the unit
Landform(s): mountain
Slope gradient: 0 to 5 percent
Parent material: volcanic ash derived from dacite till derived from andesite
Restrictive feature(s): duripan at 40 to 60 inches
Seasonal high water table: approximately 12 inches
Flooding frequency none
Ponding frequency: none

Soil loss tolerance (T factor): 4
Wind erodibility group (WEG): 3
Wind erodibility index (WEI): 86
Land capability class, non-irrigated: 6s
Land capability class, irrigated:
Drainage class: moderately well drained
Hydric soil class: no
Hydrologic group: B

Representative soil profile:		Texture	Permeability	Available Water Capacity	pH	Kw	Kf
A1 --	0 to 2 in	ashy loamy sand	moderate	0.2 to 0.3 in	5.6 to 6.0	.15	.17
A2 --	2 to 12 in	ashy sandy loam	moderate	1.5 to 2.0 in	5.6 to 6.0	.15	24
2Bw1 --	12 to 30 in	very gravelly medial loam	moderate	3.1 to 4.5 in	5.6 to 6.0	.15	32
2Bw2 --	30 to 36 in	very gravelly medial clay loam	moderate	1.1 to 1.2 in	5.6 to 6.0	.15	32
2BC --	36 to 45 in	very gravelly medial sandy clay loam	moderate	1.3 to 1.4 in	5.6 to 6.0	.10	32
2Bqm --	45 to 60 in	cemented material	slow				

Ecological Site / Plant Association: ASHY GLACIAL PRAIRIE 40-60PZ (R003XY020OR)

Racing and similar soils

Extent: about 40 percent of the unit
Landform(s): mountain
Slope gradient: 0 to 3 percent
Parent material: volcanic ash derived from dacite and/or alluvium derived from andesite over till derived from andesite
Restrictive feature(s): none
Seasonal high water table: approximately 0 inches
Flooding frequency none
Ponding frequency: frequent

Soil loss tolerance (T factor): 4
Wind erodibility group (WEG): 2
Wind erodibility index (WEI): 134
Land capability class, non-irrigated: 6s
Land capability class, irrigated:
Drainage class: poorly drained
Hydric soil class: yes
Hydrologic group: C

Take a moment to look at the map unit description, then hit the "**CLOSE**" button on the map unit report toolbar to return to the main menu

7. The next issue to address is the need to produce a report for the park which contains the requested interpretations for "**Hazard of Off-Road or Off-Trail Erosion**" and "**Potential for Damage to Soil by Fire".**

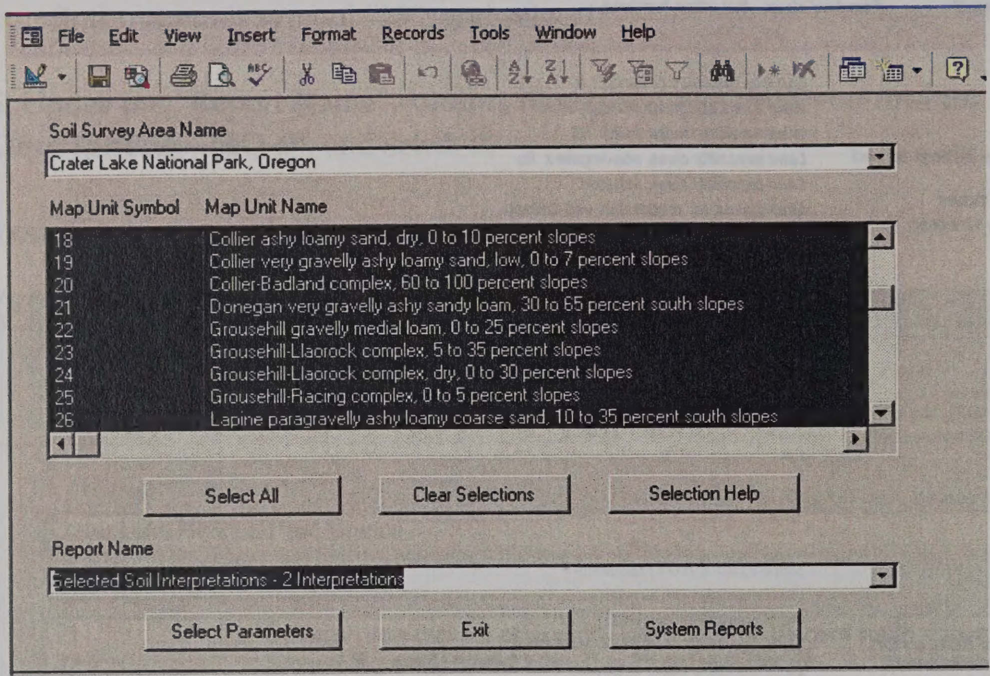
Unfortunately, if we went to the "standard tables" these interpretations would be found in two separate tables, "**Table FOR-2**", and "**Table FOR-5**", and would contain extraneous interpretations that the park does not need for this evaluation. They have requested that these two interpretations be run for all soil map units in the park, and that they be provided these interpretations "side by side".

The following procedure should provide us the desired products.

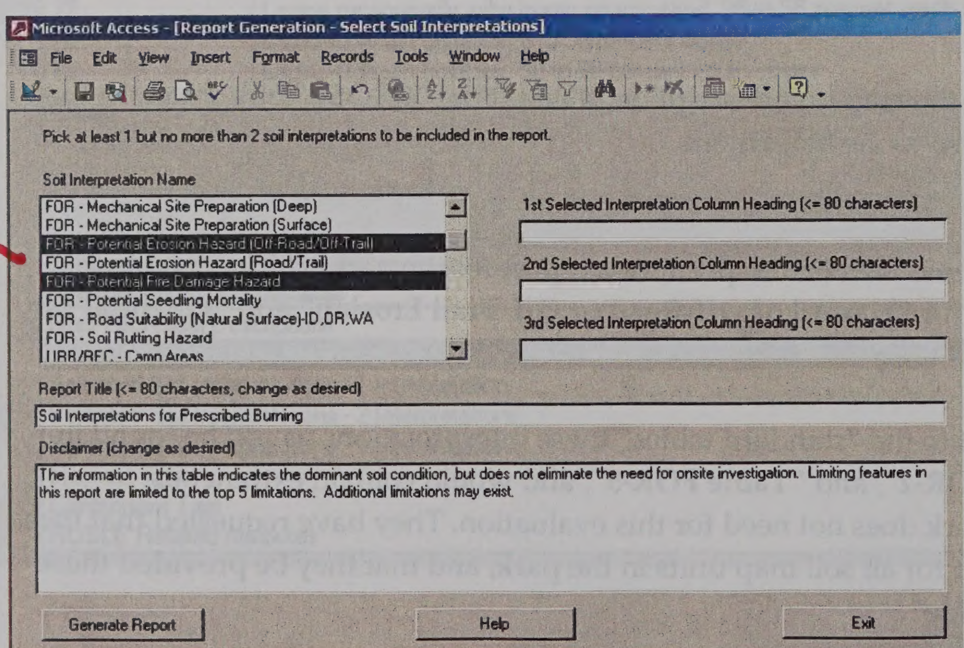
8. Hit the "**Select all**" button to highlight all the soil map units.

9. Navigate within the "**Report Name**" dialogue box until you find the option "**Selected Soil Interpretations – 2 Interpretations**" and select it.

You should see the following;



10. Now hit the "**Select Parameters**" button, and you should get the following;



Select these 2 Soil interps

use your control key to select 2nd INTERP

11. Under the "Report Title" enter the following text

Soil Interpretations for Prescribed Burning

12. Hit the "**Generate Report**" button, and you should get the following;

Soil Interpretations for Prescribed Burning

Crater Lake National Park, Oregon

The information in this table indicates the dominant soil condition, but does not eliminate the need for onsite investigation. Limiting features in this report are limited to the top 5 limitations. Additional limitations may exist.

Map Symbol and Soil Name	Pct of Map Unit	FOR - Potential Erosion Hazard (Off-Road/Off-Trail)		FOR - Potential Fire Damage Hazard	
		Rating Class and Limiting Features	Value	Rating Class and Limiting Features	Value
1:					
Anniecreek	60	Slight		Low	
				Texture/coarse fragments	0.10
Stirfry	20	Histosol - Not rated		Moderate	
		Histosol taxonomic order	1.00	Texture/coarse fragments	0.50
Riverwash	15	Not rated		Not rated	
2:					
Badland	80	Not rated		Not rated	
3:					
Badland	70	Not rated		Not rated	
Stirfry	25	Histosol - Not rated		Moderate	
		Histosol taxonomic order	1.00	Texture/coarse fragments	0.50
4:					
Castlecrest	85	Slight		Low	
5:					
Castlecrest, dry	80	Slight		Low	
6:					
Castlecrest, low	85	Slight		Low	

This concludes Exercise 1

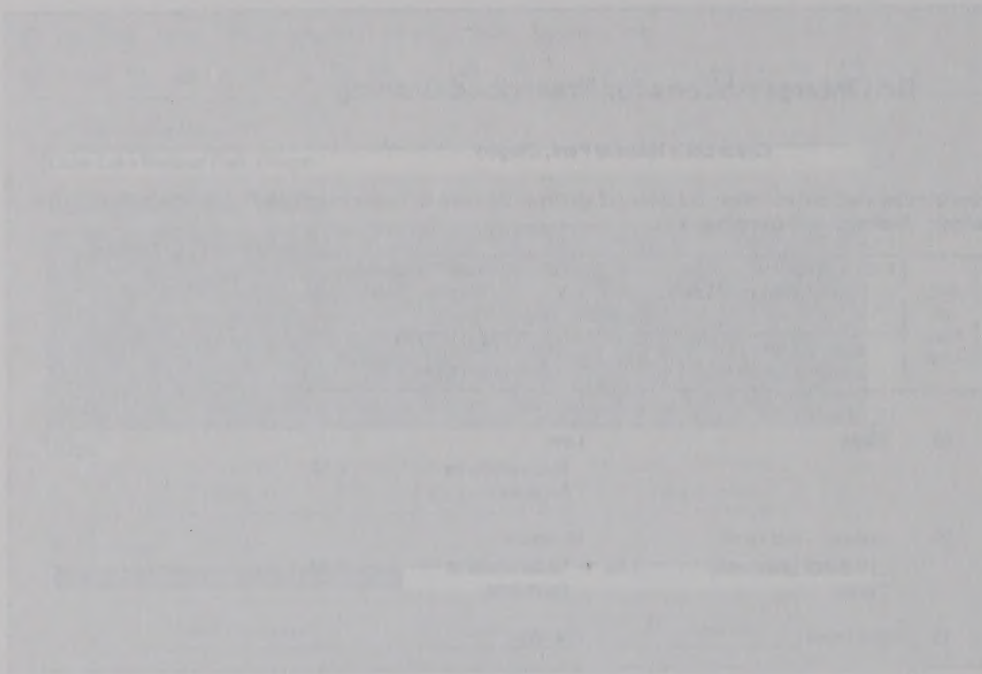
EXIT MS Access

CLOSE "SOIL-DB" window

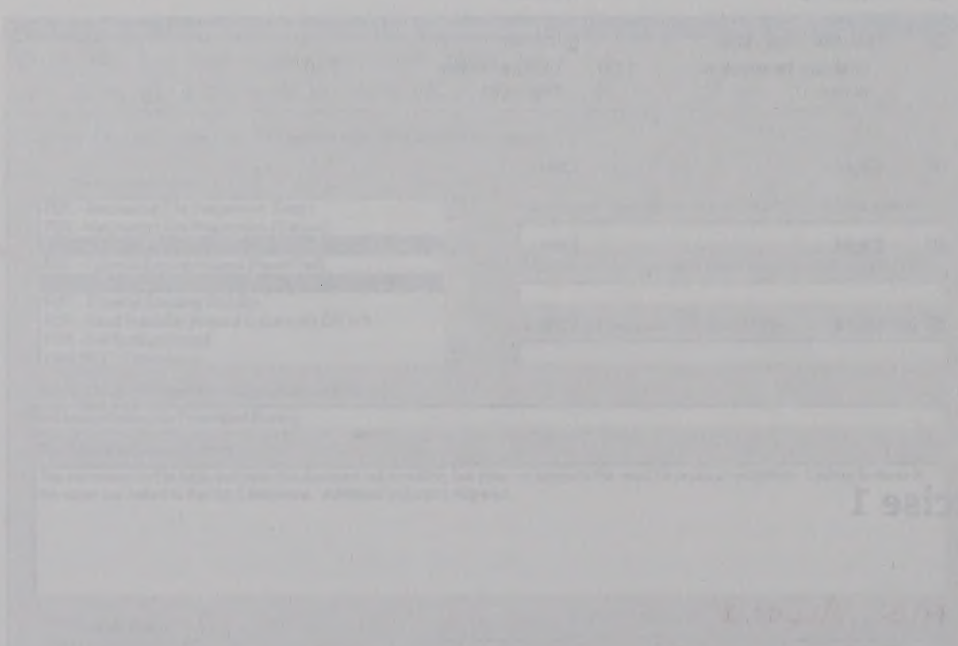
8. Hit the "Select all" button to highlight all the soil map units

9. Navigate within the "Report Name" dialogue box until you find the option "Selected Soil Interpretations – 2 Interpretations" and select it.

You should see the following:



10. Now hit the "Select Parameters" button, and you should get the following:



Exercise 2:

Familiarization with the Components of a Soil Survey and the Development of a Soil Interpretive Map

OBJECTIVE: To utilize the Soils Data Viewer and fundamental Geographic Information System (GIS) concepts, to visualize and develop "products" from the various components of the Soil Survey Geographic database (SSURGO) for Crater Lake National Park. The intent in this exercise is not to provide specific training in the use of the Soil Data Viewer, however, we will use it as a "tool" to gain access into the SSURGO database to facilitate "product development".

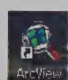
DATA SETUP

The soils data used in this exercise, along with the satellite imagery are already loaded on the computer, and are configured to be accessed without any manipulation.

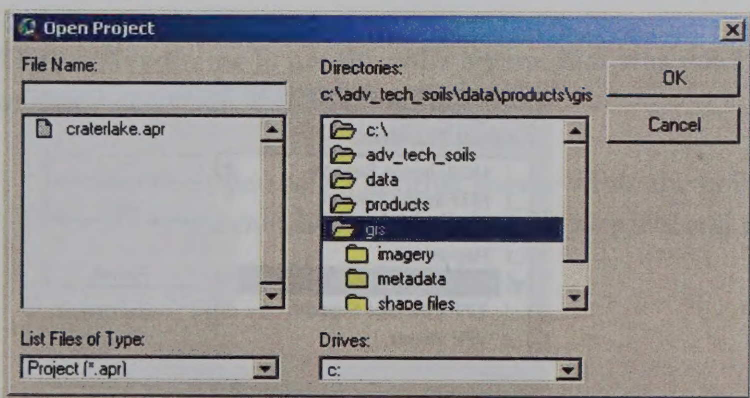
For this exercise, the data path is **C:\Adv_Tech_Soils\Data\Products\GIS)**

EXERCISE STEPS

Step 1: Start ArcView, Open an existing project, Confirm that the Soil Data Viewer and Geoprocessing extensions are active

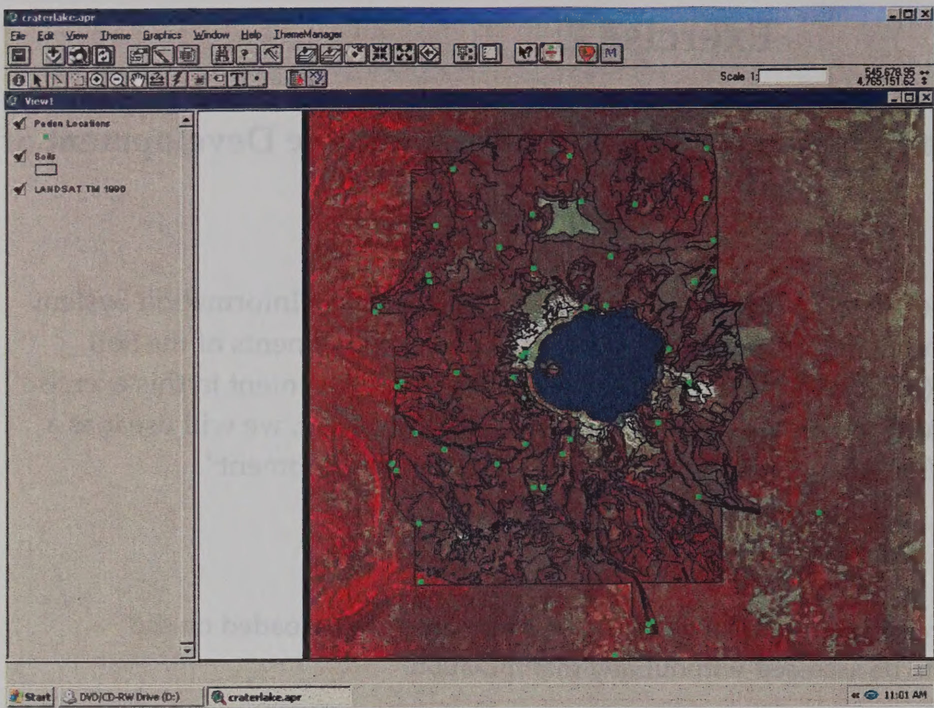
- Use the Desktop shortcut icon to start **ArcView.** 

- Select **Open Existing Project**



Select **"craterlake.apr"**

You should see the following;



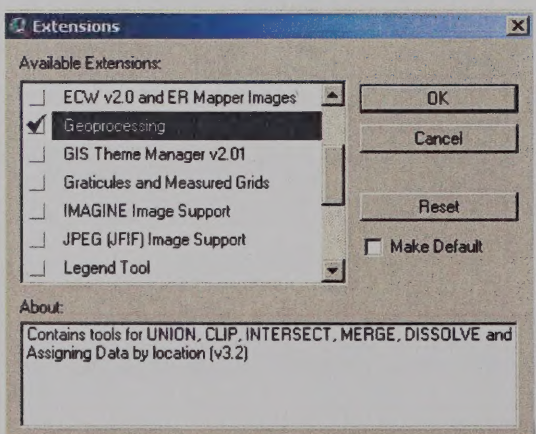
What has been loaded into the view are the **Pedon Locations** (green dots), **Soils** (black polygons), as well as a **LANDSAT TM** scene from 1996,

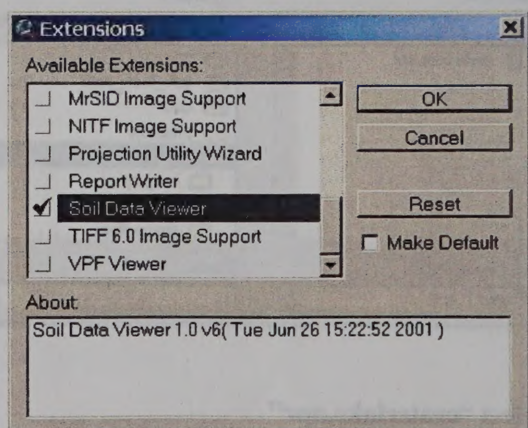
Next, confirm that the ArcView extensions that are needed in this exercise are active.

- Select **File → Extensions** on the Menu bar.

An **Extensions** window now appears.

- Confirm that the **Geoprocessing,** and **Soil Data Viewer extensions** are selected
- Click **OK.**





The **Soil Data Viewer** button was added to the ArcView button bar when we loaded several ArcView extensions in the previous step

- Confirm that the **Soil Data Viewer** button is present. 

- If it is not present, it needs to be loaded, following the previous procedures **This button will appear to be "grayed" at this time, since we do not have a soil theme active.**

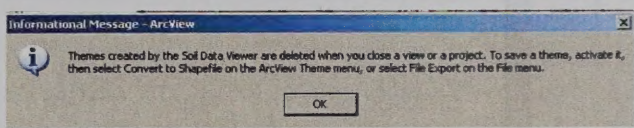
- **NOTE**: A soil theme must be active to start the Soil Data Viewer !!!!!!!!

Activate a Soil Theme to the View

- Click on the theme **Soils** to make it active

- The **Soil Data Viewer** button becomes active at the same time.

- Now click on the activated **Soil Data Viewer** button , which will then activate the Soil Data Viewer, opening up the **Soil Data Viewer dialog box**. You will also get the following message, which informs the user that interpretive maps are temporary until the user saves them as a shapefile



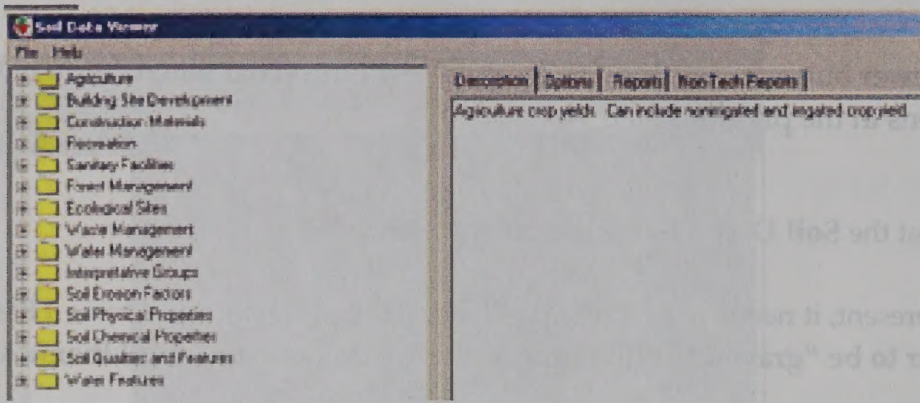
- **NOTE**: If you activate another theme while the Soil Data viewer is open, this message is displayed across the bottom of the dialogue box:

"The active theme is not the soils theme that was used to start the Soil Data Viewer. Activate the original soils theme."

- **NOTE**: If you select another theme while the Soil Data Viewer is minimized, the icon on the task bar shows **Disabled.** Select the original soil theme to reactivate it.

Hit **OK** to proceed

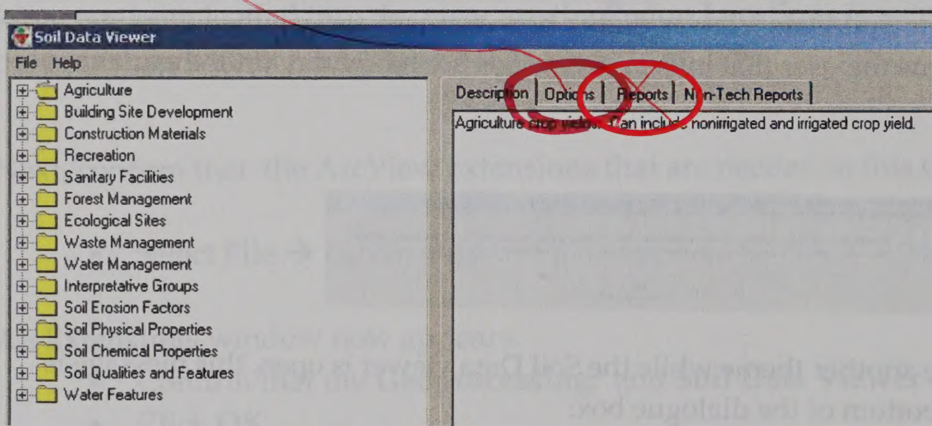
You should see the following

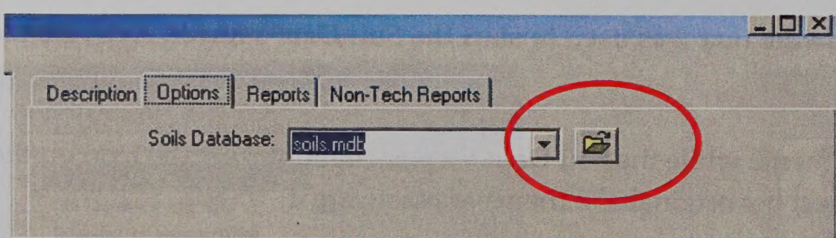


Selecting a Soil Database

You may select which soil attribute database to use with the Soil Data Viewer, but you may select only one database at a time.

- The first time the Soil Data Viewer opens, a message tells you to select a soil database. Click the **Options** tab, then click the browse button .





Browse to the folder where the soil database is located.
C:\Adv_Tech_Soils\Data\Products\GIS\SOIL_DB

- Select the database *soils* then click **Open**. The Soils Database window should now show **soils.mdb** as the active database.

NOTE: The first time a soil database is selected, it is added to the choice list on the **Options** tab. The next time you want to use this database, you may select it from the choice list instead of browsing to it. The database chosen will remain active until another one is selected.

Running the Soil Data Viewer After Selecting the Soils Database

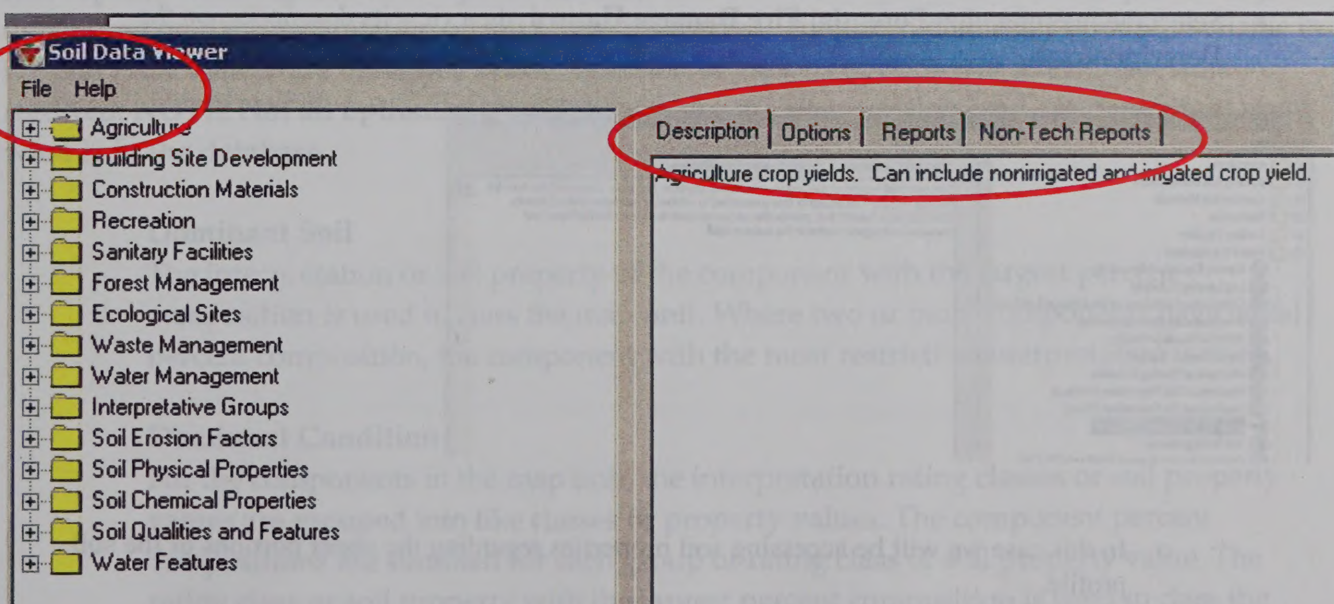
- The Soil Data Viewer has one dialog box that is divided into two windows. The left window displays a list of interpretive groups and soil properties. The right window has four tabs, **Description**, **Options, Reports**, and **Non-Tech Reports**. The **Description** tab is displayed when the Soil Data Viewer opens.

- The **File** menu also allows access to these functions mentioned in Step 2 above: **Change Database**, the **Description** tab, the **Options** tab, the **Reports** tab, the **Non-Tech Reports** tab, and **Exit**.

- Select the **Help** menu to access the help functions: **Contents, Index**, and **Search**. Select **About Soil Data Viewer** for information about the installed version. Select **Contents** for specific information on the Soil Data viewer Help capabilities.

- Take a moment to browse various options available

- You can navigate to the various options by double-clicking on them. Most will open up to provide additional selections. When finished, just close the **Help Topics: Soil Data Viewer** window.



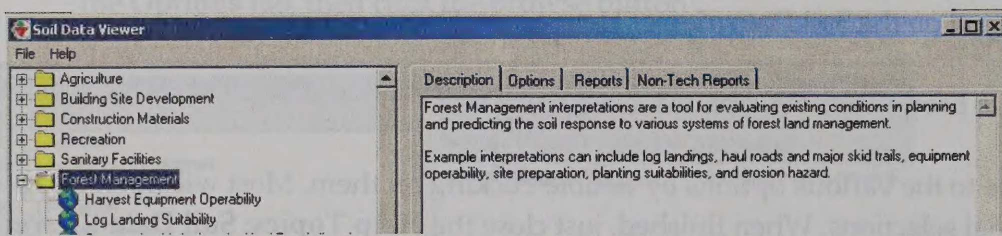
Select an Interpretation or Soil Property

The left window of the ***Soil Data Viewer*** dialog box displays a list of the available interpretations and soil property reports. These items are grouped into folders. The folders are organized by land use, interpretative group, soil feature, and other features.

In this example will are interested in depicting the potential effects of fire on the soil resources in Crater Lake National Park. We will show that the National Soils Information System (NASIS) has developed numerous soil interpretations based upon various soil physical, chemical, and biological soil properties.

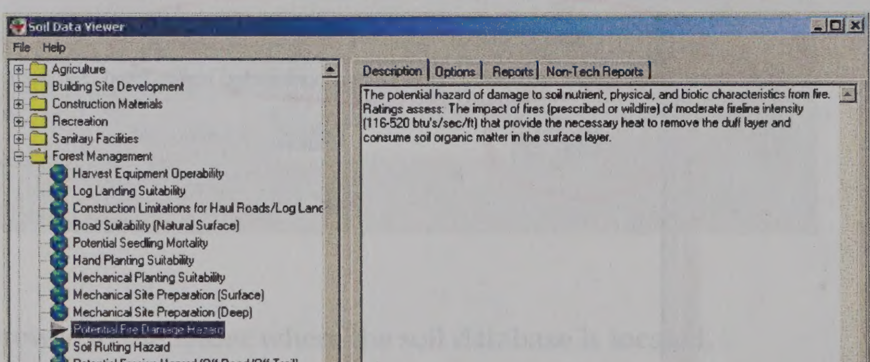
This is only one example, but the attempt is to show that attempting to access the soils database, and link to some of the various soil properties without a sufficient understanding of the soil data structure can be facilitated by the use of the Soil Data Viewer.

- Select the folder, **Forest Management**, then view a description of the folder contents in the window on the **Description** tab.



- Click the button next to the **Forest Management** folder to view the available interpretations or soil property reports.

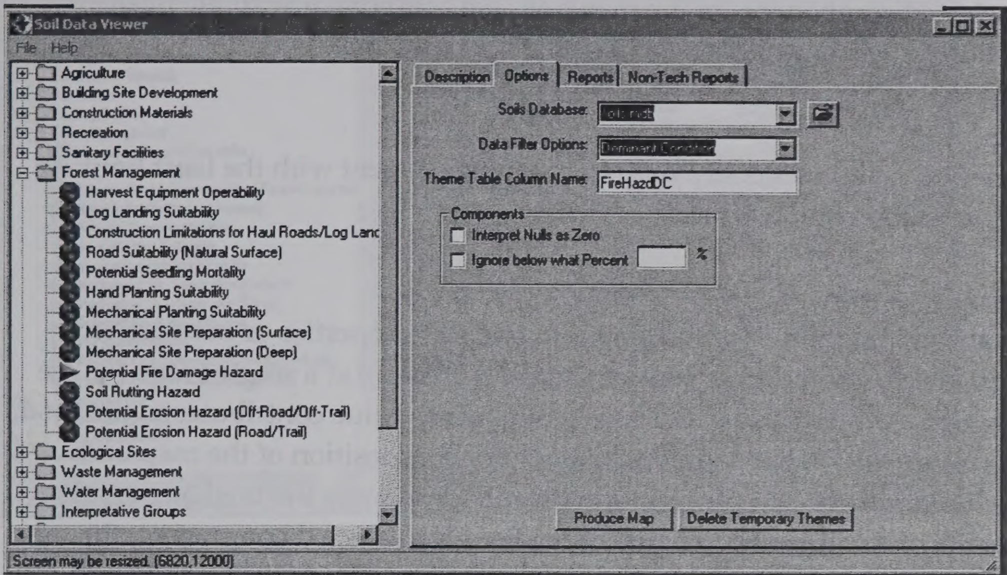
- Select the interpretation **Potential Fire Damage Hazard**, then view its description on the **Description** tab.



  - In this case we will be accessing soil properties regarding the upper portions of the soil profile.

- Click the **Options** tab to select processing options for an interpretation or soil property.

You should see the following



Select Processing Options

The processing options that appear on the **Options** tab depend on the interpretation or soil property that you select, and the available data for the soil database. These options are set automatically by the Soil Data Viewer.

Soil Database is the database you selected when the Soil Data Viewer was started previously in this exercise. This should be **soils.mdb**

For **Data Filter Options** , you can accept the default value, or click the button to select another data filter option. Based upon the interpretation chosen, these will vary. The data filter options vary, depending on the interpretation or soil property selected. The seven data filter options available in the Soil Data Viewer are described below. Selection of various options will affect the results received. **NOTE: Not all options are available for every interpretation, and are dependent upon what is in the database**

Dominant Soil
The interpretation or soil property of the component with the largest percent composition is used to class the map unit. Where two or more components have equal percent composition, the component with the most restrictive interpretation is used.

Dominant Condition
For the components in the map unit, the interpretation rating classes or soil property values are grouped into like classes or property values. The component percent compositions are summed for each group of rating class or soil property value. The rating class or soil property with the largest percent composition is used to class the

map unit. Where two or more interpretation groups have equal percent composition, the group with the most restrictive interpretation is used.

Most Limiting
Out of all the selected components in the map unit, the component with the most limiting restriction for the interpretation is used.

Least Limiting
From all the selected components in a map unit, the component with the least limiting restriction for the interpretation is used.

Weighted Average
Weighted average is a method of processing numeric soil properties or productivity values (i.e., crop yields) for multiple components and arriving at a single value for the map unit. Weighted average means that each components value contributes to the final answer, based (weighted) on the component's percent composition of the map unit. Components with larger percent composition contribute more to the final answer than minor components of small percent composition. For each selected component, the numeric property or productivity value is multiplied by the decimal percent of the component percent composition. These values are summed for all selected components and represent the weighted average value for the map unit.

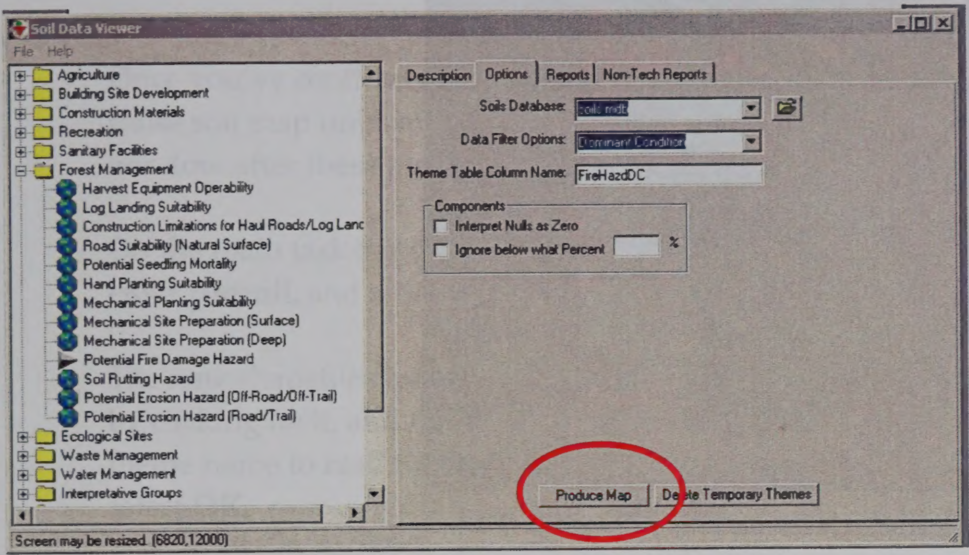
Presence/Absence
All the components in a map unit are evaluated for the presence or absence of an interpretation or soil property. The map unit can be classed where the interpretation is present in all components, absent in all components, partially present in all components, or unknown. This processing method is used for the hydric soil map unit rating.

All Components
All the components in a map unit are evaluated for the soil property or feature. This component processing method is more commonly used for physical or chemical soil properties, flooding, ponding, or water table.

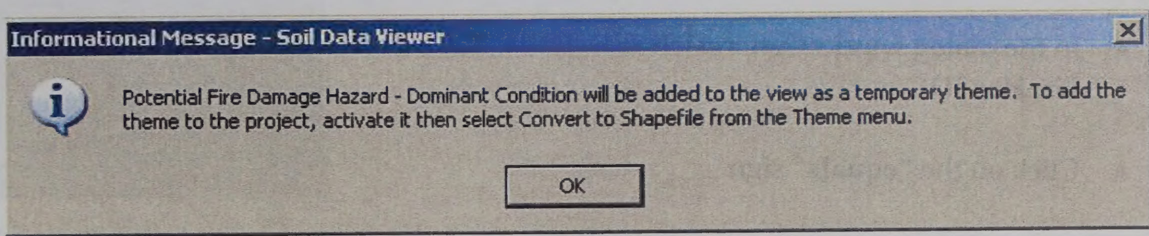
For the purpose of this exercise, select Dominant Condition (Default) !!!!!!

- **Theme Table Column Name** is automatically selected based upon the interpretation chosen. This is the MS ACCESS table Column Name that will be queried from the soil database. This should be **FireHazdDC**
- The options in the **Components** area are not required to be entered in this example .

- **Click** the **Produce Map** tab to develop a report on soil interpretation selected



The following message will appear, informing you that the themes created within Soil Data Viewer are temporary until the user saves them as a shapefile.

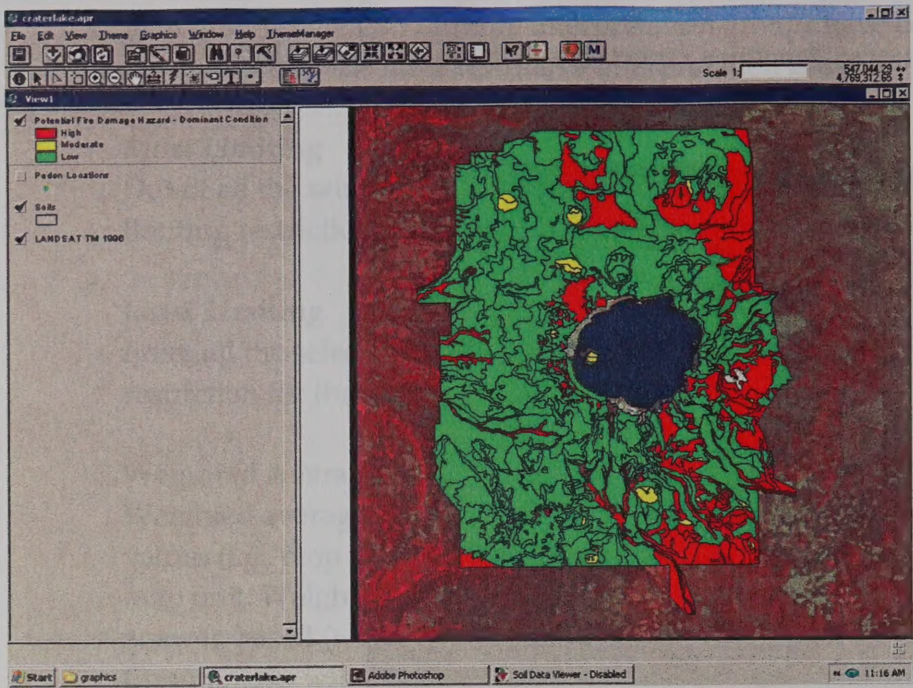


- Hit OK to close the **Informational Message – Soil Data Viewer** window

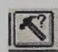
- Minimize the **Soil Data Viewer** window

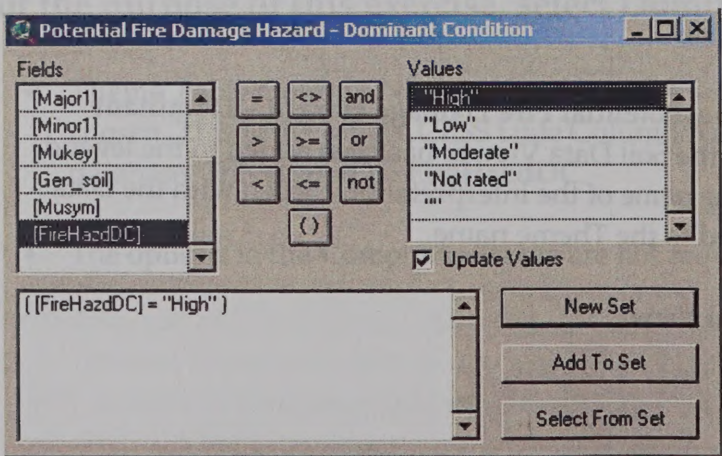
- You will see that the temporary theme, **Potential Fire Damage Hazard – Dominant Condition** which you just created in the Soil Data Viewer has been added to the legend, with the naming convention being the name of the interpretation chosen with the Data Filter Option selected being appended to the Theme name.

- **Click** to add this theme to the current View



Now lets take it a step further, in which all we really want to create is a map with those areas having a HIGH Potential Fire Damage Hazard rating

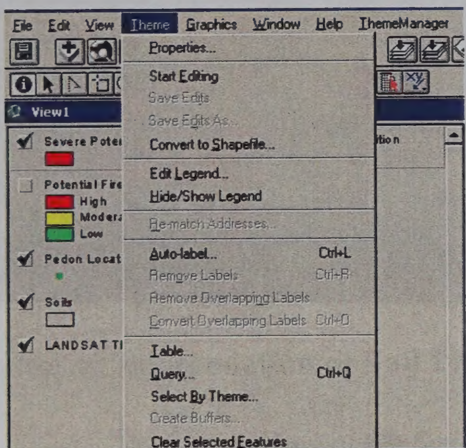
- Activate the theme we just created from Soil Data Viewer
- Hit the Query Builder Button 
- In the dialog window on the left side, under the **Fields** choices, <u>**double click**</u> on **FireHazdDC**
- Click on the "**equals**" sign
- Under the **Values** choices, <u>**double click**</u> on the rating **"High"**
- The Query Builder window should look like this

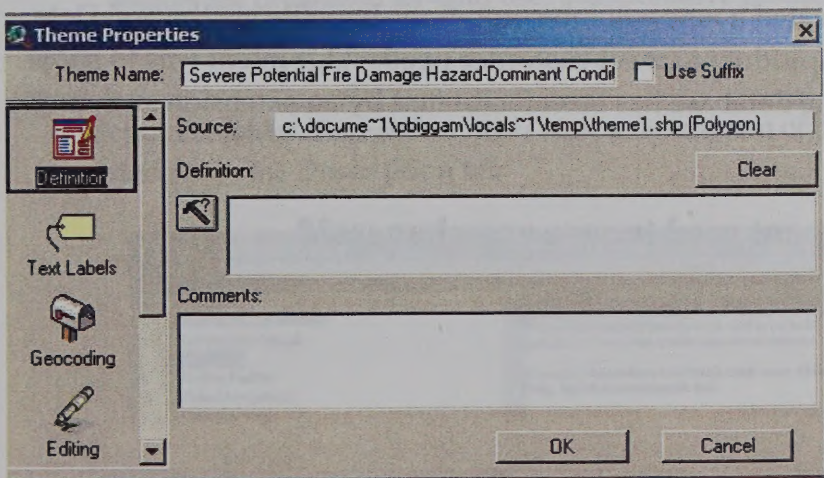


- Once you've confirmed these selections, hit the **New Set** button, this should highlight those soil map units meeting these selected conditions on screen. You can now close this window after these polygons are displayed

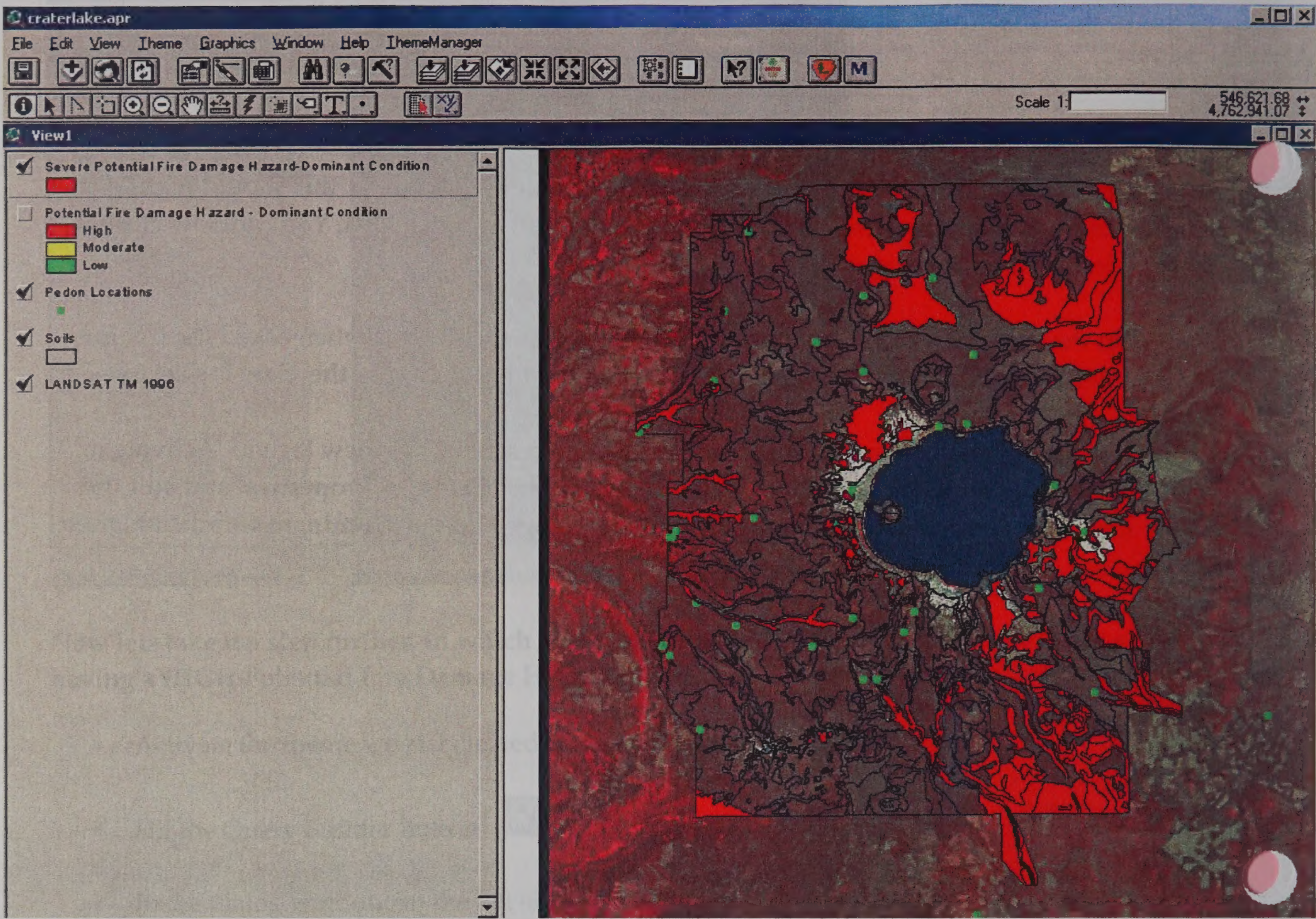
  On the main task bar select **Theme ->Convert to Shapefile,** and when asked for a name, enter **firesoil,** and when asked to **Add shapefile to as theme to the view ?,** select **yes**

- The new shapefile **firesoil.shp** should now be present in the View legend. Activate it, by clicking on it, and from the main task bar select **Theme -> Properties**, and edit the theme name to read **Severe Potential Fire Damage Hazard-Dominant Condition,** then select **OK.**





- Feel free to edit the color for this new theme if desired



Congratulations !, You have just created a new soil interpretation shapefile via the Soil Data Viewer. You have also developed a product to meet customer needs. Our intent was to show the accessibility into the soil attribute database has been facilitated by an extension such as the Soil Data Viewer.

****Exit from ArcView – You do not need to save any changes****

EXERCISE 3

Creating a Soil Report outside of ArcView: Paths and Trail Example

Sites **without** ArcView may use the Soil Data Viewer to produce tabular reports that display soil data and information. Tabular reports require a soil attribute database in Soil Survey Geographic Database (SSURGO) version 2 format, loaded into an Access 97 or Access 2000 database. Sites **with** ArcView may also access the Soil Data Viewer from the desktop to produce tabular reports. However, soil maps may be generated only when the Soil Data Viewer is started from ArcView.

In this example, the Soil Data Viewer is accessed from the Windows Desktop.

Start the Soil Data Viewer from the Desktop

- To start the Soil Data Viewer from the Desktop, click the **Soil Data Viewer icon,** in the upper right corner of your desktop.

Select/Confirm a Soil Database

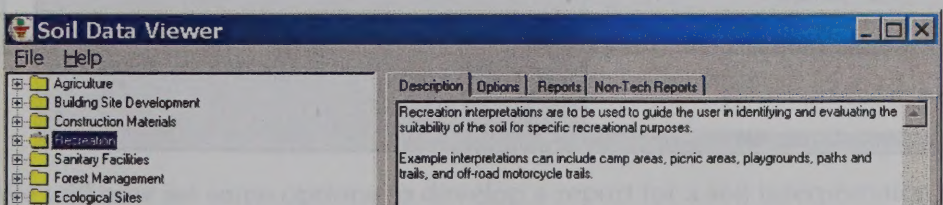
- You may select which soil attribute database to use with the Soil Data Viewer, but you may select only one database at a time.

- Since we have already started Soil Data Viewer in previous steps, we will not be prompted to select a soils database, but we will confirm that **soils.mdb** is active.

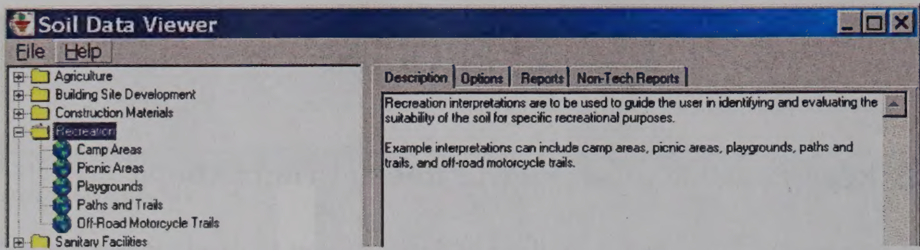
Select an Interpretation or Soil Property

The left window of the *Soil Data Viewer* dialog box displays a list of the available interpretations and soil property reports. These items are grouped into folders. The folders are organized by land use, interpretative group, soil feature, and other features.

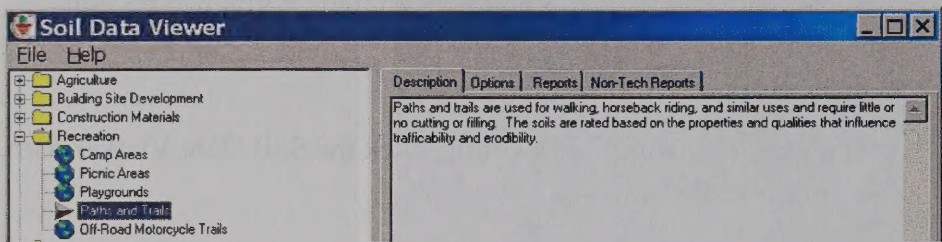
- Select the folder, **Recreation**, then view a description of the folder contents in the window on the **Description** tab.



- Click the ⊞ button next to the **Recreation** folder to view the available interpretations or soil property reports.

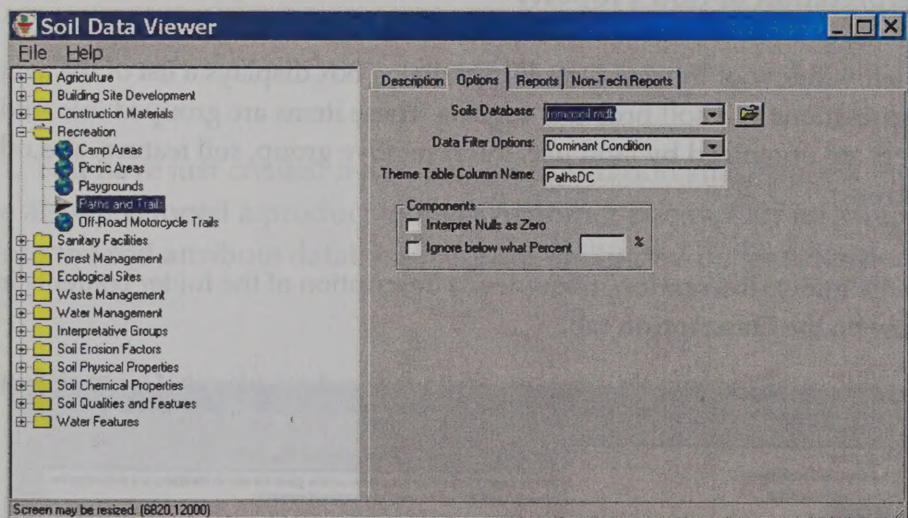


- Select the interpretation **Paths and Trails**, then view its description on the **Description** tab.



- Click the **Options** tab to select processing options for an interpretation or soil property.

Select Processing Options
The processing options that appear on the **Options** tab depend on the interpretation or soil property that you select, and the available data for the soil database.



Soil Database is the database you selected when the Soil Data Viewer was started previously in this exercise.

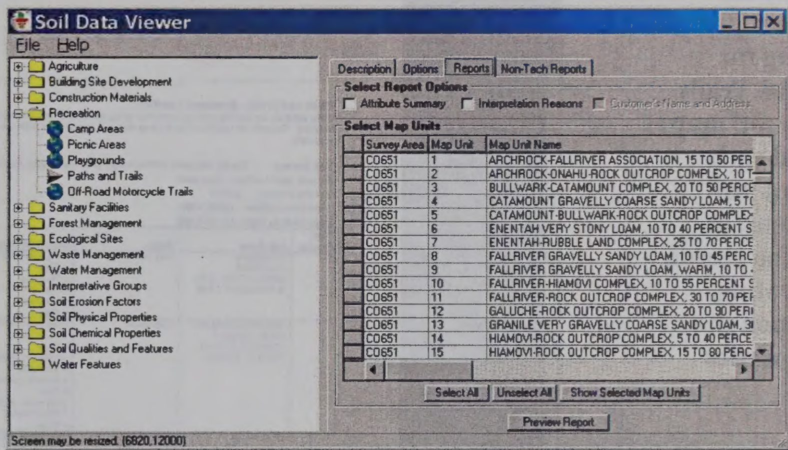
For **Data Filter Options**, accept ~~the default value, Dominant Condition~~

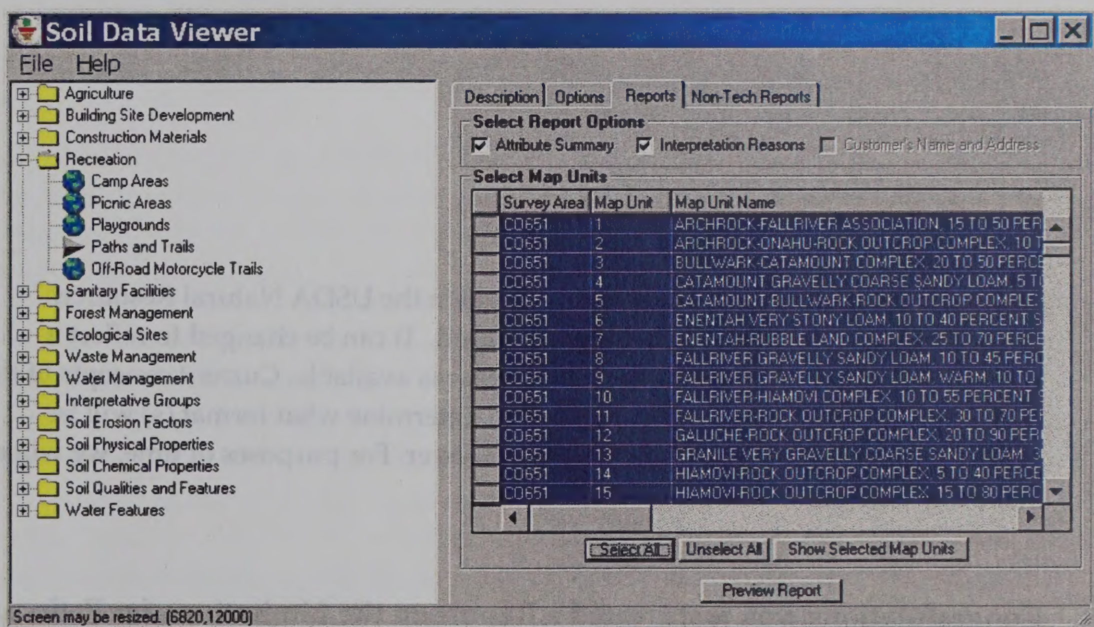
Select OPTION - MOST LIMITING

Theme Table Column Name is automatically selected based upon the interpretation chosen. This is the MS ACCESS table Column Name that will be queried from the soil database.

The options in the **Components** area are not required to be entered in this example.

- Click the **Reports** tab to develop a report on soil interpretation selected



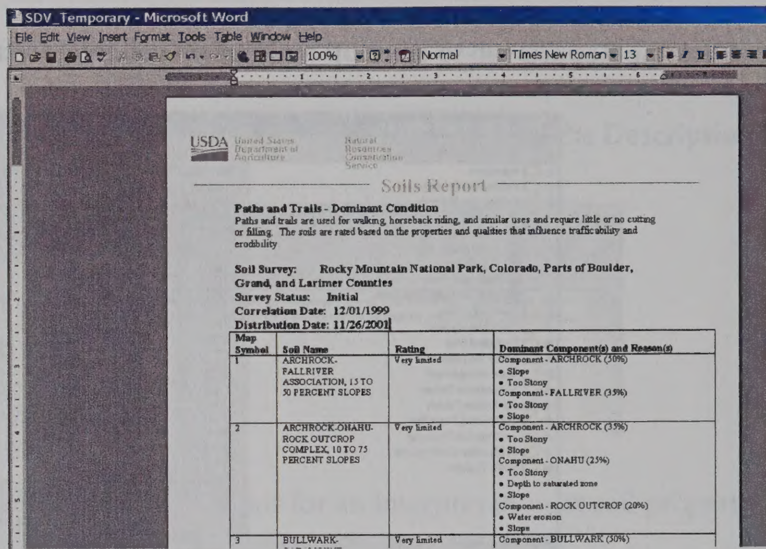


We will now set some options to develop a report for a soil interpretation for **Paths and Trails** suitability, based upon specific soil properties identified within the interpretation, and the soil map units we want analyzed. Soil Data Viewer will then run a report based upon these parameters.

- Click on **Attribute Summary** (this will provide specifics soils properties queried)

- Click on **Interpretation Reasons** (this will provide the reason the rating was given)
- We want to run it on all soil map units, so click on **Select All**
- When these have been selected, click **Preview Report,** which will begin processing the query (this will take a few moments, please be patient)

The result is a MS Word file which contains the rating for Paths and Trails for each soil map unit, and each dominant soil component, as well as the reason for the rating, based upon the soil properties present


SDV_Temporary - Microsoft Word

Soils Report

Paths and Trails - Dominant Condition
Paths and trails are used for walking, horseback riding, and similar uses and require little or no cutting or filling. The soils are rated based on the properties and qualities that influence trafficability and erodibility

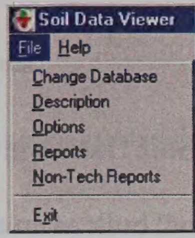
Soil Survey: Rocky Mountain National Park, Colorado, Parts of Boulder, Grand, and Larimer Counties
Survey Status: Initial
Correlation Date: 12/01/1999
Distribution Date: 11/26/2001

Map Symbol	Soil Name	Rating	Dominant Component(s) and Reason(s)
1	ARCHROCK-FALLRIVER ASSOCIATION, 15 TO 50 PERCENT SLOPES	Very limited	Component - ARCHROCK (50%) • Slope • Too Stony Component - FALLRIVER (35%) • Too Stony • Slope
2	ARCHROCK-ONAHU-ROCK OUTCROP COMPLEX, 10 TO 75 PERCENT SLOPES	Very limited	Component - ARCHROCK (35%) • Too Stony • Slope Component - ONAHU (25%) • Too Stony • Depth to saturated zone • Slope Component - ROCK OUTCROP (20%) • Water erosion • Slope
3	BULLWARK-	Very limited	Component - BULLWARK (50%)

This example depicts a report template in which the USDA Natural Resources Conservation Service (NRCS) letterhead is used. It can be changed to reflect a particular NPS unit for which the soil database is available. Current concepts of the NPS Identity Program are being pursued to determine what format (s) will be available and utilized within the Soil Data Viewer. For purposes of time, we will not make any changes within this exercise.

Congratulations, you just created a Report on the Limitations for Paths and Trails, based upon soil properties, for Crater LakeNational Park.

- Exit from MS Word (we do not need to save this file)



- Exit from the Soil Data Viewer

You are now finished with the training exercise. If time permits, feel free to develop another report, using a soil interpretation and or query of your choice.

Background on the Soil Data Viewer

Soil Data Viewer is a tool built as an extension to ArcView ® that allows you to easily create soil-based thematic maps. Soil Data Viewer shields users and applications from the complexity of the soil database and incorporates rules for appropriate use of soil data. It provides an easy to use tool for geospatial analysis of soil information for resource assessment and management

Why Soil Data Viewer?

- The soil survey attribute database associated with the spatial soil map is a complicated database with more than 50 tables. The Soil Data Viewer provides users access to soil interpretations and soil properties while shielding them from the complexity of the soil database. Each soil map unit (polygons) may contain multiple soil components that have different use and management. The Soil Data Viewer makes it easy to compute a single value for a polygon and display results, relieving the user from the burden of querying the database, processing the data and joining and linking to the spatial map. The Soil Data Viewer contains processing rules for appropriate use of the data.

- What this means to personnel is that they can access a very robust soils database without requiring them to obtain additional expertise.

Overview of Soil Data Viewer

- The Soil Data Viewer provides easy access to a soil database to process and display soil data and information. It displays soil data and information in tabular reports and produces maps in ArcView. The Soil Data Viewer offers nearly 100 soil reports, each with several data processing options. Available reports vary by soil survey.

Soil Data Viewer 3.0 Changes

- Soil Data Viewer 3.0 includes improvements suggested by many users across the country. A summary of the changes follows:

- Microsoft® Access databases and ESRI® ArcView shapefiles that operated with the Soil Data Viewer version 2.0 **will not operate** with Soil Data Viewer version 3.0.

- The Soil Data Viewer generates tabular soil reports from a soil attribute database for sites without ArcView.

- The Soil Data Viewer generates both soil maps and tabular reports for sites with a digitized soil layer and ArcView.

- Soil reports are formatted as Microsoft® Word documents.
- The Soil Data Viewer generates reports of non-technical soil reports when the data is available.
- Version 3.0 includes nearly 100 reports.
- Users select which database the Soil Data Viewer uses to process and generate reports and maps.
- Soil reports may be customized with the Park Unit name and address.

Soil Data Viewer 3.0 Data Requirements

For Soil Reports

- The Soil Data Viewer requires a soil attribute database in Soil Survey Geographic Database (SSURGO) version 2 format, loaded in Microsoft® Access Database 97 or 2000 to produce tabular soil reports. Access databases that operated with the Soil Data Viewer version 2.0 **will not operate** with Soil Data Viewer version 3.0.

For Soil Maps

- The Soil Data Viewer requires a digitized soil map in ArcView shapefile format, and a soil attribute database in Soil Survey Geographic Database (SSURGO) version 2 format, loaded into a Microsoft Access 97 or 2000 database. Displaying soil data and information as a map requires an ESRI® ArcView® 3.1 or greater.

Produce a Soil Report

- Sites **without** ArcView may use the Soil Data Viewer to produce tabular reports that display soil data and information. Tabular reports require a soil attribute database in Soil Survey Geographic Database (SSURGO) version 2 format, loaded into an Access 97 or Access 2000 database. Sites **with** ArcView may also access the Soil Data Viewer from the desktop to produce tabular reports. However, soil maps may be generated only when the Soil Data Viewer is started from ArcView.

REFERENCES

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USDA- Natural Resources Conservation Service, Soil Data Viewer User's Guide, Stand-alone Version 3.0, 2001

http://www.itc.nrcs.usda.gov/soildataviewer/about.htm

SOFTWARE REFERENCES

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http://www.esri.com

NPS GIS Theme Manager. Vers 2.01. ArcView extension. National Park Service, 2001.
http://www.nature.nps.gov/im/apps/thmmgr/

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http://www.itc.nrcs.usda.gov/soildataviewer/about.htm

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http://www.nature.nps.gov/im/apps/thmmgr/

SoLIM DEMO

Advanced Technologies for Soil Survey: Soil-Land Inference Model (SoLIM)

William R. Effland, Ph.D.
U.S. Department of Agriculture
Natural Resources Conservation Service

Advanced Soil Survey Technologies

- Soil-Land Inference Model (SoLIM)
- Geographic Information Systems (GIS)
- Remote Sensing
- Landscape Visualization

Acknowledgements

This presentation on the Soil-Land Inference Model (SoLIM) research was primarily developed from previous work completed by Drs. A-Xing Zhu and James Burt at the UWI-Madison Department of Geography.

Also, Dr. Berman Hudson, former SSD Director, encouraged my early work on this project.

Outline of SoLIM Presentation

I. Challenges in Conducting Soil Survey

II. The SoLIM Approach

III. Results of SoLIM Research
- A. Map Products
- B. Documenting Soil-landscape Models

Challenges in Conducting Soil Survey

Knowledge Documentation

The Polygon-based Model

Soil-Landscape Model Building

Polygon Maps → $S <= f(E)$

Manual Delineation

Photo Interpretation

The Manual Mapping Process

(source: Zhu and Burt, 2003)

Consequences of Current Soil Survey Methods

Accuracy of Products?
- Misplacement of soil lines
- Map unit design - Inclusions and complexes
- Modal soil properties

Speed of Updating?
- Non-digital format = Not reusable
- Slow and costly
- Digitization – another slow, costly, error prone step

(source: Zhu and Burt, 2003)

Addressing The Challenges:

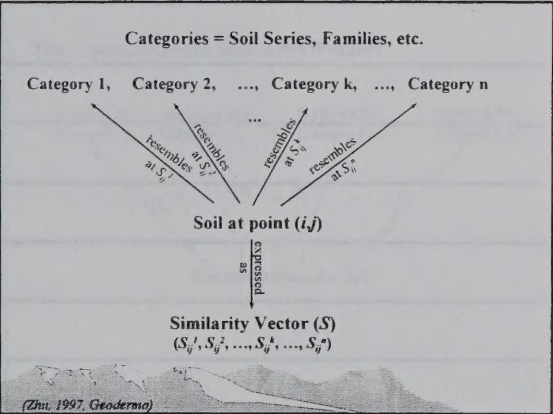
Overcoming the Polygon Map Model

The Similarity Model

Similarity representation in parameter space

Objects are represented as a vector of similarity values

(source: Zhu and Burt, 2003)



Addressing The Challenges:

Overcoming the Polygon Map Model

The Similarity Model

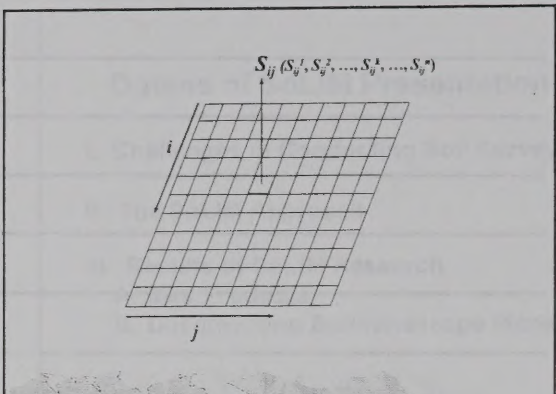
Similarity representation in parameter space

Objects are represented as a vector of similarity values

Raster representation in geographic space

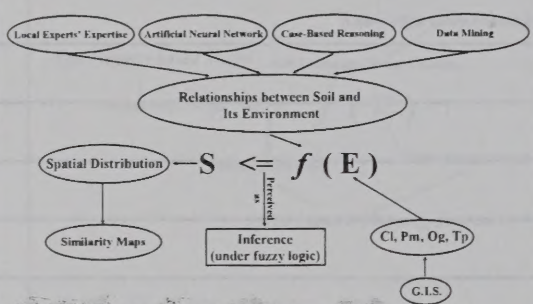
Spatial details are represented at the spatial resolution of a raster data model

(source: Zhu and Burt, 2003)



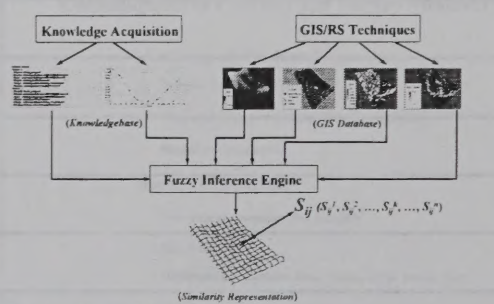
(source: Zhu and Burt, 2003)

Overcoming the Manual Mapping Process



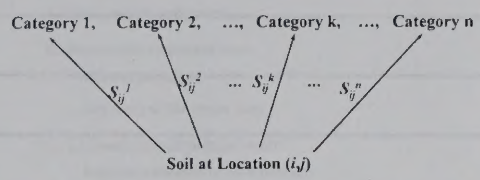
(Zhu, 1997, Geoderma; Zhu, 2000, Water Resources Research)

Overcoming the Knowledge Documentation Problem



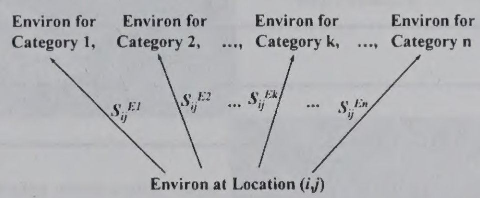
(source: Zhu and Burt, 2003)

The Soil Similarity Vector:



(source: Zhu and Burt, 2003)

The Environmental Similarity Vector:



(source: Zhu and Burt, 2003)

Under the Soil-Landscape Model Concept:

S_{ij}^{k} can be approximated by S_{ij}^{Ek}

thus

$$S_{ij}^{E}\,(S_{ij}^{E1},\ S_{ij}^{E2},\ \ldots\ S_{ij}^{Ek},\ \ldots\ S_{ij}^{En})$$

$$\downarrow$$

$$S_{ij}\,(S_{ij}^{1},\ S_{ij}^{2},\ \ldots\ S_{ij}^{k},\ \ldots\ S_{ij}^{n})$$

(source: Zhu and Burt, 2003)

Use of the Soil-Landscape Model Paradigm:

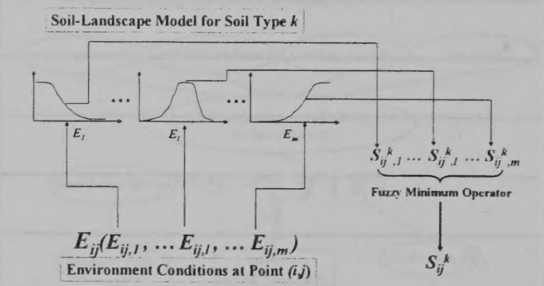
The soil landscape model for a specific soil contains:

A. The typical environmental conditions for the specific soil

B. How this specific soil varies when the environmental conditions deviate from its typical environmental conditions

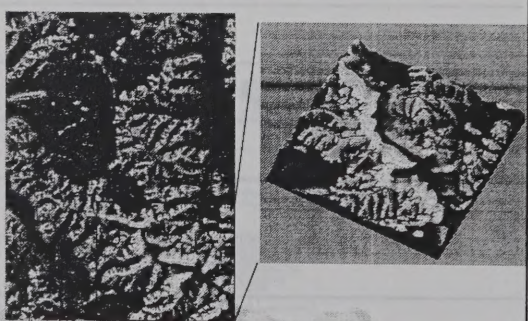
(source: Zhu and Burt, 2003)

The Basic Process of Computing S_{ij}^{E}: Fuzzy Inference Model



(source: Zhu and Burt, 2003)

SoLIM Inference Result



(source: D. Simonson, 2003)

Results of SoLIM Research

I. Map Products

A. Fuzzy membership maps

B. Raster soil categorical maps

Uncertainty maps

Accuracy of the raster map

C. Conventional soil polygon maps

Reports inclusions in each polygon

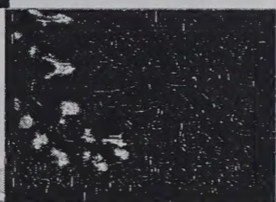
Comparison with the conventional soil polygon maps

D. Continuous soil property maps

(source: Zhu and Burt, 2003)

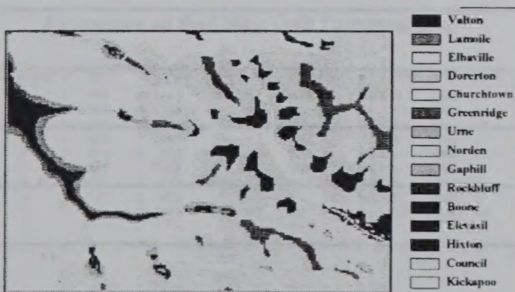
I. SoLIM-derived Map Products

A. Fuzzy membership maps



(source: Zhu and Burt, 2003)

Map Products B. Raster soil categorical maps

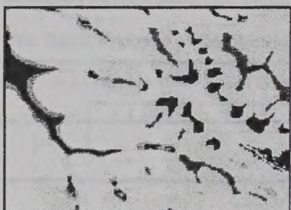


(source: Zhu and Burt, 2003)

Map Products

C. Uncertainty Maps Using Soil Series For Local Conditions

(source: Zhu and Burt, 2003)

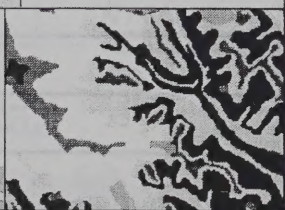


Comparisons of Raster and Polygon Soil Maps

← Map from SoLIM

Accuracy of the map?

Conventional Soil Map →



(source: Zhu and Burt, 2003)

Accuracy of the Raster Soil Map?

Comparison between SoLIM and Soil Map against field data (Raffelson series)

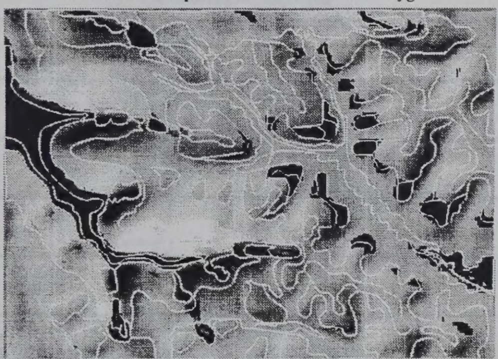
	Sample Size = 99		
	Overall	In Complexes	In Single
SoLIM	83.8%	89%	81%
Soil Map	66.7%	73%	61%
	Mismatches		
	Correct	Total Mismatches	Percentage
SoLIM	24	30	80%
Soil Map	4	30	13%

(source: Zhu and Burt, 2003)

C. Conventional Polygon-based Soil Maps

(source: Zhu and Burt, 2003)

Estimate and Report Inclusions in Each Polygon



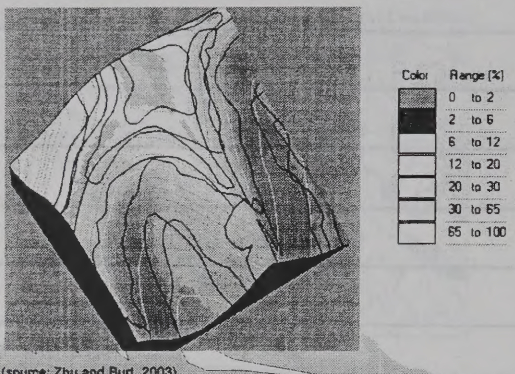
(source: Zhu and Burt, 2003)

Estimates of Soil Map Unit Composition

PolygonID	1st	Pcnt	2nd	Pcnt	3rd	Pcnt	4th	Pcnt	5th	Pcnt	Other	Pcnt
1	7	83.3	3	16.7	NILL	0	NILL	0	NILL	0	Other	0
2	6	92.1	3	3.8	5	3.5	7	0.5	12	0.1	Other	0
3	7	88.8	6	4.8	30	4.2	11	1.3	23	0.6	Other	0.3
4	6	86.8	7	11.7	5	1.5	NILL	0	NILL	0	Other	0
5	5	63.3	6	36.7	NILL	0	NILL	0	NILL	0	Other	0
6	3	35.7	5	32.1	6	32.1	NILL	0	NILL	0	Other	0
7	3	64.3	1	35.7	NILL	0	NILL	0	NILL	0	Other	0
8	6	71.3	5	16.2	11	8.7	3	3.8	NILL	0	Other	0
9	7	88.3	23	7.2	20	1.7	30	1.5	6	0.7	Other	0.6
......												

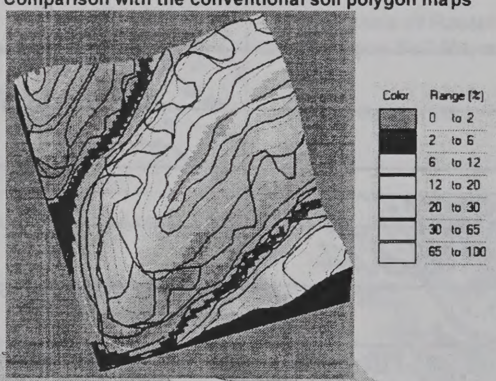
(source: Zhu and Burt, 2003)

Comparison with the conventional soil polygon maps



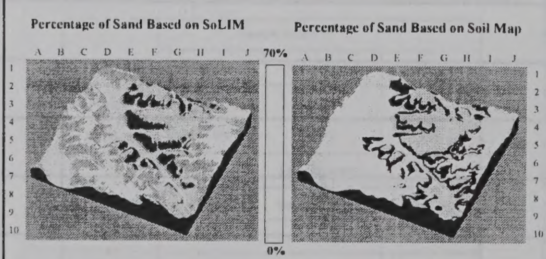
(source: Zhu and Burt, 2003)

Comparison with the conventional soil polygon maps



(source: Zhu and Burt, 2003)

D. Continuous Soil Property Maps



(source: Zhu and Burt, 2003)

Results from SoLIM Research

I. Map Products

II. Documented Soil-Landscape Model (Knowledge)

A. Catenary sequences

B. Dichotomous keys

C. Soil environment descriptions

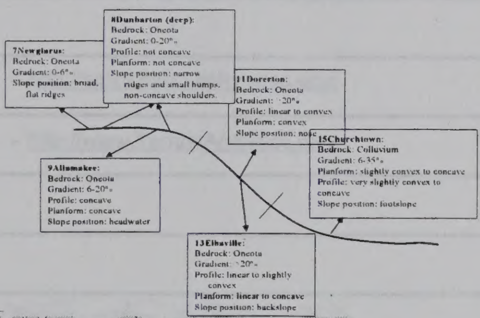
D. Tacit points

Or

E. Fuzzy membership functions

(source: Zhu and Burt, 2003)

A. Catenary Sequence



(source: D. Simonson, 2003)

B. Dichotomous Keys

Key to Soil Series

Oneota

Slope Position

Ridge ⟶ Valton

Middle
Lamoille
Dorerton
Elbaville

Gradient

< 20% ⟶ Lamoille

> 20%
Dorerton
Elbaville

Planform

Convex ⟶ Dorerton

Linear-Concave ⟶ Elbaville

Bottom ⟶ Churchtown

(source: Zhu and Burt, 2003)

Soil-Environment Descriptions

Dorerton

Geology:	Oneota
Elevation:	1150 – 1250 ft
Gradient:	>30%
Profile Curvature	Linear - convex
Planform Curvature	Convex
Slope Position:	Middle (side slopes)
Other Notes:	Wooded; below lamoille, on slope noses (divides)

Elbaville

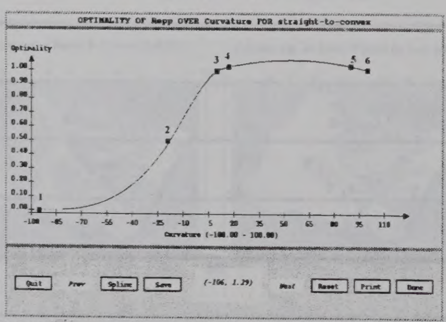
Geology:	Oneota
Elevation:	1150 – 1250 ft
Gradient:	>30%
Profile Curvature	Concave – linear – slightly convex
Planform Curvature	Concave - linear
Slope Position	Middle
Other Notes	Wooded; on straight slopes and drainage ways

(source: Zhu and Burt, 2003)

D. Tacit Points

(source: Zhu and Burt, 2003)

E. Fuzzy Membership Functions



(source: Zhu and Burt, 2003)

Results of SoLIM Research

I. Map Products

II. Extracted Soil-Landscape Model (Knowledge)

Catenary sequences

Dichotomous keys

Soil environment descriptions

Tacit points

Or

Fuzzy membership functions

Can Be

Studied

Revised or improved

Reused in future updates

(source: Zhu and Burt, 2003)

Internet Sources

– http://solim.geography.wisc.edu/

– http://www.TerrainAnalytics.com

Soil Survey Technologies

- Geographic Information Systems (GIS)
  - Soil Data Viewer
  - Internet Delivery of Digital Soil Survey Data
  - Natural Resources Inventory, Assessment and Management
- 3-Dimensional Visualization
  - ESRI ArcGIS and ArcScene
  - Terrain Analytics 3dMapper
  - Digital Elevation Models
  - Digital Orthophotography
- Soil-Land Inference Model (SoLIM)
  - Cooperative Research with the Univ. of WI Geography Department
  - Raster-based Predictive Mapping
- Remote Sensing
  - Geophysical tools
  - Light Detection and Ranging (LiDAR)
  - Hyperspectral Imagery

FINAL ASSESSMENT

Final Project:
Developing and Finishing the Pre-Map

Objective: Develop and finish the pre-map of the Juniper Draw Quad by building on the map you have been creating in ERDAS Imagine.

Approach:

1) Build the knowledge-based decision tree to split out the four major soil-landscape-vegetation units present on the Juniper Draw Quad.
    a. Meander Belts
        i. Slopes <=2% AND
        ii. Relative Elevation to the Powder River <5m
    b. Eroded Breaks
        i. Iron (Soil Enhancement Band Ratio 3/7) >=67 AND
        ii. Slope >10%

    (*Note: You have probably completed this much by Wednesday noon!*)
    c. Uplands
        i. NOT Meander Belts
        ii. NOT Eroded Breaks
        iii. Relative Elevation to the Powder River >=75m
    d. Alluvial Fans and Hills
        i. NOT Meander Belts
        ii. NOT Eroded Breaks
        iii. NOT Uplands

    (Tentatively "everything else" until classification refined after field work.)

2) Refine "Meander Belts" into two separate classes based on <u>vegetation</u>:
    a. Cottonwood dominant areas
    b. Grass dominant areas

    (*Hint: Look at FVI values for pixels in Cottonwood vs. Grass areas; decide on tentative FVI value for break between classes.)*

3) Refine "Uplands" into four separate classes based on <u>slope</u>.
    (*Hint: Look at MOU for specified slope breaks.)*

4) "Finish" the Pre-Map:
    a. Clump: ERDAS Imagine, Interpreter, Utilities, GIS Analysis
    b. Eliminate: same path as above
    c. Convert raster to vector map (polygon map): ArcGIS

    (*Note: Nephi will lead everyone through the map finishing process.)*

REFERENCES

www, usu, edu search for remote sensing/GIS lab (RS/GIS lab)
gap analysis

REMOTE SENSING/GIS GLOSSARY

absorptance - A measure of the ability of a material to absorb electromagnetic energy at a specific wavelength.

albedo - Ratio of the amount of electromagnetic energy reflected by a surface to the amount of energy incident upon it.

azimuthal - Map projection displaying characteristics of true direction.

band-A wavelength interval in the electromagnetic spectrum. For example, in Landsat images the bands designate specific wavelength intervals at which images are acquired.

buffer - A zone of a specified distance around coverage features. Both constant- and variable-width buffers can be generated for a set of coverage features based on each feature's attribute values. The resulting buffer zones form polygons-areas that are either inside or outside the specified buffer distance from each feature. Buffers are useful for proximity analysis (e.g., find all stream segments within 300 feet of a proposed logging area).

Cartesian coordinate system - A two-dimensional, planar coordinate system in which x measures horizontal distance and y measures vertical distance. Each point on the plane is defined by an x,y coordinate. Relative measures of distance, area, and direction are constant throughout the Cartesian coordinate plane.

classification - Assigning pixels of a continuous raster image to discrete categories.

conformal - Map projection representing properties of true shape.

continuous - Raster data layers containing quantitative and related values. There may be one or more layers.

coordinate system - A reference system used to measure horizontal and vertical distances on a planimetric map. A coordinate system is usually defined by a map projection, a spheroid of reference, a datum, one or more standard parallels, a central meridian, and possible shifts in the x- and y-directions to locate x,y positions of point, line, and area features.

coverage - 1. A digital version of a map forming the basic unit of vector data storage in ArcInfo. A coverage stores geographic features as primary features (such as arcs, nodes, polygons, and label points) and secondary features (such as tics, map extent, links, and annotation). Associated feature attribute tables describe and store attributes of the geographic features.

2. A set of thematically associated data considered as a unit. A coverage usually represents a single theme such as soils, streams, roads, or land use.

datum - A horizontal or vertical reference system that map transformations are based upon.

developable surface - A flat surface that can be easily flattened by being unrolled (i.e. cone)

digital image-An image where the property being measured has been converted from a continuous range of analogue values to a range expressed by a finite number of integers, usually recorded as binary codes from 0 to 255, or as one byte.

digitizing - The process of converting information shown on an analog map into a digital format of x and y coordinates for use in a computer.

edge matching - An editing procedure to ensure that all features that cross adjacent map sheets have the same edge locations. Links are used when matching features in adjacent coverages.

electromagnetic radiation - Energy transmitted through space in the form of electric and magnetic waves.

electromagnetic spectrum-Continuous sequence of electromagnetic energy arranged according to wavelength or frequency.

enhancement – A process that makes an image more interpretable to the human eye.

equal area - Map projection representing properties of true proportion.

equidistance - Map projection representing properties of true distance measuring.

EROS Data Center (EDC) - Facility of the U.S. Geological Survey at Sioux Falls, South Dakota, that archives, processes, and distributes images.

geographic information system (GIS) - An organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.

false color image - A color image where parts of the non-visible EM spectrum are expressed as one or more of the red, green, and blue components, so that the colors produced by the Earth's surface do not correspond to normal visual experience. Also called a false-color composite (FCC). The most commonly seen false-color images display the very-near infrared as red, red as green, and green as blue.

histogram - A graph of data distribution or a chart of the number of pixels that have each possible data file value.

indices - Used to create output images by mathematically combing the DN values of different bands of an image.

Landsat - A series of unnamed earth-orbiting NASA satellites that acquire multispectral images in various visible and IR bands.

map projection - A mathematical model that transforms the locations of features on the Earth's surface to locations on a two-dimensional surface. Because the Earth is three-dimensional, some method must be used to depict a map in two dimensions. Some projections preserve shape; others preserve accuracy of area, distance, or direction. Map projections project the Earth's surface onto a flat plane. However, any such representation distorts some parameter of the Earth's surface be it distance, area, shape, or direction.

metadata - Information about data.

micrometer - A millionth of a meter

multispectral scanner-Scanner system that simultaneously acquires images of the same scene at different wavelengths.

orthorectification - Corrects for terrain displacement using a digital terrain model.

panchromatic - Single banded, grayscale images

pixel - Picture element or the smallest unit of an image.

polygon - Set of closed line elements defining an area.

raster data - Data organized in a grid of columns and rows. Also referred to as cell, grid, pixel data.

rectification - Making image data conform to a map projection system.

reflectance - Ratio of the radiant energy reflected by a body to the energy incident on it. Spectral reflectance is the reflectance measured within a specific wavelength interval.

resample - Extrapolation of data file values for the pixels in a new grid when data have been rectified or registered to another image.

resolution - A level of precision in data (i.e. spatial, radiometric, temporal, spectral)

Need to elaborate on each

scene - Area on the ground that is covered by an image or photograph.

spherical surface - Point locations based on degrees, minutes, and seconds of arc.

supervised classification - Digital-information extraction technique in which the operator provides training-site information that the computer uses to assign pixels to categories.

thematic - Qualitative and categorical data with one value per cell.

Thematic Mapper (TM) - A cross-track scanner deployed on Landsat that records seven bands of data from the visible through the thermal IR regions

topology - A term that defines spatial relationships between features in a vector layer.

unsupervised classification - Digital information extraction technique in which the computer assigns pixels to categories with no instructions from the operator.

vector - A line element.

vector format - The expression of points, lines, and areas on a map by digitized Cartesian coordinates, directions, and values.

wavelength - Distance between successive wave crests or other equivalent points in a harmonic wave.

ACRONYMS

AML
: ARC Macro Language. A high-level algorithmic language for generating end-user applications. Features include the ability to create on-screen menus, use and assign variables, control statement execution, and get and use map or page unit coordinates. AML includes an extensive set of commands that can be used interactively or in AML programs (macros) as well as commands that report on the status of ArcInfo environment settings.

AOI Area of Interest

ASTER Advanced Spaceborne Thermal Emision and Reflection Radiometer – on the Terra satellite, containing 15 bands.

AVHRR Advanced Very High Resolution Radiometer – small scale imagery produced by a NOAA satellite with 1.1 kilometer spatial resolution.

DEM Digital Elevation Model – raster data set with regularly spaced data file values representing elevation

DN Digital Number – variation in pixel density typically from 0-255

DOQ Digital Ortho Quadrangle – aerial photos, mosaicked and horizontally and vertically rectified to a map base quadrangle format.

DRG Digital Raster Graphic – a scanned topographic map registered to a map base.

DV Digital Value – synonymous for digital number DN

EDC The United States Geological Survey (USGS) EROS Data Center located in Sioux Falls, South Dakota.

EMR Electromagnetic Radiation – measured in frequency and wavelength

ETM Enhanced Thematic Mapper sensor aboard Landsat satellite

FGDC The United States Federal Geographic Data Committee. Composed of representatives of several federal agencies and GIS vendors, the FGDC has the lead role in defining spatial metadata standards, which it describes in the Content Standards for Spatial Metadata.

MIR	Mid-infrared portion of the electromagnetic spectrum
MODIS	Moderate Resolution Imaging Spectroradiometer – on the Terra satellite with 36 bands at 250, 500, and 1000 meter resolution.
MSS	Multispectral Sensor aboard Landsat satellite
NAD	North American Datum
NIR	Near infrared portion of the electromagnetic spectrum
NDVI	Normalized Difference Vegetation Index – (IR-RED/IR+RED) creates one-banded image highlighting greenness
RGB	Red, Green, Blue color gun assignments
ROI	Region of Interest
SPOT	Systeme Pour l'Observation de la Terre – French sensor.
TIN	Triangulated Irregular Network is a DEM with a network of triangles at randomly located terrain points
TIR	Thermal-infrared portion of the electromagnetic spectrum
TM	Thematic Mapper Landsat sensor aboard Landsat satellite
WGS	World Geodetic System

DIVISION S-5—SOIL GENESIS, MORPHOLOGY & CLASSIFICATION

The Soil Survey as Paradigm-based Science

Berman D. Hudson*

ABSTRACT

Thomas S. Kuhn developed the paradigm theory of science. The soil survey is an example of paradigm-based science. The soil–landscape model, on which the soil survey is based, is an operative paradigm. An extreme reliance on tacit knowledge, the knowledge gained by experience, creates serious inefficiencies, both in learning the soil-landscape paradigm and in disseminating the information resulting from its application. This article introduces concepts important to understanding paradigm theory and the nature of tacit knowledge. Among these are elements of Gestalt psychology, the theory of natural families, maps as conveyors of knowledge, and the linguistic nature of human perception. Students and field soil scientists should be provided explicit instruction concerning the paradigm on which soil mapping and interpretation are based. I also recommend that more of the soil geographic relationships discovered while making detailed soil maps be described and published so that the knowledge can be communicated to others.

THE TERM *paradigm* and the phrase *paradigm shift* have been used with increasing frequency. These words refer to ideas first put forth by physicist-philosopher Thomas S. Kuhn (1962, 1970). The term *paradigm*, as conceived by Kuhn, refers to a broad explanatory concept that provides a foundation and structure for an entire field of scientific inquiry. Kuhn proposed a new model for the way progress is made in a scientific field, arguing that a guiding paradigm is a prerequisite to significant progress. Kuhn's theory of paradigm-based science was a radical challenge to the conventional thinking of his time. Kuhn explained his theory in exhaustive detail and supported it with numerous examples from the physical sciences. The following is only a brief summary of his work.

The former view of scientific progress assumed a gradual, uninterrupted accumulation of knowledge and understanding (Kuhn, 1970). Science was seen as a slow, inexorable march forward, with each generation adding marginally to the information it inherited and then passing on the slightly larger total to the next generation. Kuhn rejected this view. He argued that science is not entirely a slow, methodical process. Instead, Kuhn asserted, cumulative scientific progress is interrupted periodically by episodes of intense conflict between supporters of competing paradigms.

Paradigms and human perception are intricately related. A paradigm determines, to a large extent, how a scientist views the world. It often is necessary, however, for a scientist to change the was he or she views certain aspects of the world in order to learn a paradigm. Since concepts relating to human perception are so important to understanding paradigms, several pertinent topics from psychology and philosophy will be introduced. These include the concepts of tacit knowledge (Polanyi, 1966), natural families (Wittgenstein, 1976), gestalt shifts (Kohler, 1980), and Hanson's (1969, p. 108 and 124–146) concepts of "seeing." These topics are especially important in understanding how Kuhn's paradigm theory can be applied to the soil survey.

USDA-SCS, Federal Building, Room 152, 100 Centennial Mall North, Lincoln, NE 68508–3866. Contribution of USDA-SCS, National Soil Survey Center. Received 22 Apr. 1991. *Corresponding author.

Published in Soil Sci. Soc. Am. J. 56:836–841 (1992).

KUHN'S PARADIGM THEORY

Kuhn (1970) stated that a paradigm is based on "... one or more past scientific achievements that some particular scientific community acknowledges for a time as supplying the foundation for its further practice." He went on to specify two essential characteristics of a successful paradigm. First, the paradigm should be capable of capturing the imagination of a group of scientists and attracting them away from competing modes of scientific activity. Second, it should be nonspecific and open-ended enough to leave many interesting problems for practitioners to solve.

Preparadigm Science

Kuhn asserted that, in the absence of a paradigm, all facts that could pertain to an area of study are likely to seem equally relevant. As a result, scientific practice tends to be a nearly random activity. Perhaps the best-documented example (Kuhn, 1970; Shapiro, 1987) of preparadigm science is that of the 19th century physician Ignaz Semmelweis and his search for the cause of childbed or puerperal fever. In the 19th century, a large percentage of women in hospitals died horribly of childbed fever — a massive infection following childbirth. Knowing nothing of the germ theory of disease, Semmelweis was forced to rely on trial and error. Aside from the contention that the illness was caused by "cosmic–telluric" influences, medical science of the day had no theories to offer. Among other possible causes, Semmelweis assessed the psychological effect of priests passing through the wards to give last rites to dead patients and whether women lay on their back or sides while giving birth. He eventually noted that patients attended by medical students had a much higher mortality rate than those attended by midwives. It was common practice in the hospital for medical students to go to the wards and examine women after a morning session conducting autopsies. When a colleague died of symptoms similar to childbed fever after sticking himself with a needle during an

autopsy, Semmelweis saw a possible connection. Perhaps students were transmitting some harmful substance from the cadavers to the women they examined. To test this, he mandated that students clean their hands thoroughly following autopsies. As a result the incidence of childbed fever declined dramatically. Semmelweis did not understand why his solution worked. The explanation was provided by Pasteur, with his germ theory of disease, which gave a reason for doctors to be clean.

A less dramatic, but simpler, example of preparadigm science is the effort of medieval alchemists to turn base metals into gold. These researchers operated with no guiding paradigm — or one which was extremely simplistic. They knew nothing about the atomic structure of matter and very little about the properties of metals. Their "research" consisted of trying everything possible that came to mind. It is interesting to note that these endeavors, carried out with no effective paradigm, are not even considered science by most people.

Paradigm-based Science

Kuhn (1970) contended that, in order for a scientific field to make substantive progress, a dominant guiding concept or paradigm must eventually arise. A paradigm enables a group of scientists to focus its efforts on a narrow range of problems. When they can take a paradigm for granted, scientists no longer need to explain the meaning of each concept used. Furthermore, they are not required to justify their field anew in each major work. Instead, they can concentrate with confidence on the esoteric problems that the paradigm and existing knowledge define for them. A paradigm enables the scientific community to reach a consensus concerning which problems are important and which techniques to solve them are appropriate.

A paradigm provides the practitioners of a mature specialty with an ordered view of what the world and their science are like. It does not have to answer all of the outstanding questions in a field in order to be accepted by a scientific community. Instead, as Kuhn demonstrated with numerous examples, a scientific community need only make an intuitive judgment that the paradigm will lead them in the right direction.

Kuhn (1970) argued convincingly that modern scientists, especially in the natural and physical sciences, are specifically trained for paradigm-based research — or what he referred to as "normal science" or "puzzle-solving." In fact, few practicing scientists are aware that there is any other kind of science. Such individuals are fortunate; working in a field with a successful paradigm can be extremely rewarding and productive. Failures are rare. Scientists practicing normal science or puzzle-solving under the auspices of a paradigm are comfortable in the knowledge that, with proper skill and ingenuity, they can solve a puzzle that no one has solved before. Furthermore, they are practically assured of getting meaningful and publishable results. A particularly striking example of paradigm-based science as puzzle-solving is the factorial field plot experiment common in agronomy.

Kuhn (1970) pointed out that, in normal or paradigm-based science, attention is focused on a narrow range of esoteric problems. This both enables and forces the scientist to investigate narrow problems in detail that would be impossible without a paradigm. An operative paradigm makes it possible for a science to move fast and penetrate deeply into the field under study. The astounding progress of many scientific disciplines has been made possible by interactive communities of practitioners united under a common paradigm.

Scientific Revolution

Kuhn (1970) cited numerous cases in which the kind of intense study made possible by a paradigm actually brought about its downfall. As research continues, more and more facts can be uncovered that simply do not fit into the overall conceptual framework. Some anomalies can be accommodated by slightly adjusting the original paradigm. However, others are impossible to reconcile. Notwithstanding attempts to resolve them, they become more obvious and disturbing. The operating paradigm itself can be threatened. Unresolved anomalies can increase until the ruling paradigm breaks down and is replaced. When this occurs, the scientists soon regroup, resume normal science with the new paradigm, and begin to make progress again. The confidence and hope of individual scientists are renewed.

THE SOIL–LANDSCAPE PARADIGM

Trained soil scientists can delineate bodies of soil accurately on the landscape by directly examining less than one-thousandth of the soil below the surface. They can do this because of the validity of the soil–landscape model. A powerful paradigm, it enables soil scientists to make very accurate predictions about their world. The soil–landscape paradigm has its origin in the soil factor equation outlined by Dokuchaeiv (Glinka, 1927) and Hilgard (Jenny, 1961). This well-known equation identifies the five factors of soil formation. Soil is characterized as a function of parent material, climate, organisms, relief, and time. The equation implies that, by looking for changes in one or more of these factors as the landscape is traversed, one can accurately locate boundaries between different bodies of soil.

The original soil factor equation is itself a powerful paradigm. It meets the two requirements outlined by Kuhn. First, the idea implicit in its formulation attracted a large number of adherents, who were intrigued by its promise. They were excited by the idea that this apparently simple concept could be used as the basis for accurately locating soil boundaries and delineating bodies of soil anywhere in the world. This was a compelling idea.

Because it lacked specifics, the soil factor equation met Kuhn's second criterion for a successful paradigm. It simply is a general statement implying that soils are natural bodies that are distributed in a predictable way and in response to a systematic interaction of environmental factors. There are no details. Nothing is stated, for example, about the mechanics of how soils vary, or which properties vary in different climates. Lacking specificity, it pointed the way to a

wide variety of interesting problems for practitioners to solve.

Jenny spent much time and effort validating the soil factor equation. He developed statistical correlations relating soil properties to the individual factors of soil formation. For example, in a transect from west to east in the USA, he demonstrated that the N content of the soil surface layer increased linearly as rainfall increased (Jenny and Leonard, 1934). He and his followers discovered many such relationships. Variation in different soil properties were soon related to changes in all of the soil-forming factors. This work, culminating in Jenny's book on the factors of soil formation (Jenny, 1941) provided experimental validation of the soil factor equation. However, this work merely affirmed and added detail to the original soil factor equation. It did not modify the original paradigm or develop it further.

Since its introduction more than 90 yr ago and its subsequent validation by Jenny and his coworkers, the soil factor equation has served as a general model of soil geography. It leads to the inference that soils are organized, mappable bodies. A large organized program of normal science or puzzle-solving has taken place under the general direction of this initial paradigm. This organized program, the U.S. soil survey, has been in existence now for nearly a century.

The soil–landscape model has now become the guiding paradigm for soil survey in the USA. This more specific and more deterministic paradigm evolved from the original soil factor equation during decades of puzzle-solving by field soil scientists. Until recently (Hudson, 1990), however, the paradigm had not been written down. Instead, each new soil mapper had to learn it by trial and error.

To understand the soil–landscape paradigm, one must break faith with a widely espoused tenet of soil science: the idea that soil is a continuum on the landscape. Soil does behave as a continuum within short distances. However, it is characterized by frequent, often abrupt discontinuities that can be discerned by trained observers. The term *discontinuity*, as used here, refers to a boundary area on the landscape in which one or more of the soil-forming factors changes rapidly within a short lateral distance. A concomitant change in soil properties typically occurs at the same zone and within the same lateral distance. These abrupt soil changes at observable discontinuities make soil mapping a practical enterprise.

Understanding the soil–landscape paradigm also requires that one understand the concept of soil–landscape units. These are natural terrains resulting from the interaction of the same five factors conventionally cited in the functional equation for soil formation. A soil–landscape unit has a recognizable form and shape of the surface of the earth. It is similar to a landform, but is more narrowly defined. For example, two areas could be identified as slopes, and thus would be the same landform. However, the soil on a south aspect might be significantly different from the soil on a north aspect. Therefore, at least two soil–landscape units would be recognized within this landform. A soil–landscape unit can be thought of as a landform further modified by one or more of the soil-forming factors. (For a discussion of landforms, see Hawley and Parson, 1980.) The main elements of the soil–landscape paradigm stated below are paraphrased from Hudson (1990).

SUMMARY OF THE SOIL–LANDSCAPE PARADIGM

1. Within a soil–landscape unit, the five factors of soil formation interact in a distinctive manner. As a result, all areas of the same soil–landscape unit develop the same kind of soil. In a given soil survey area, there is a relatively small number of different soil–landscape units. Individual areas of each unit occur again and again.
2. Generally, the more different conterminous areas of two soil–landscape units are, the more abrupt and striking the discontinuity separating them. An example is the boundary between a steep backslope and a gently sloping alluvial fan at its base. Conversely, the more similar conterminous areas of two soil–landscape units are, the less striking the discontinuity separating them tends to be.
3. Generally, the more similar two landscape units are, the more similar their associated soils tend to be. Conversely, very dissimilar landscape units tend to have very dissimilar soils.
4. Adjacent areas of different soil–landscape units have a predictable spatial relationship one to another. For example, one area will always be located above another on the landscape, or between another and a stream.
5. Once the relationships among soils and landscape units have been determined for an area, the soil cover can be inferred by identifying the characteristic soil–landscape unit. The soil is examined directly only as needed to validate this relationship.

The soil–landscape paradigm makes soil mapping possible because of observable discontinuities between conterminous areas of different soil–landscape units. Conterminous soils that are distinctly different tend to be on distinctly different soil–landscape units separated by abrupt discontinuities. As a general principle, the more different two conterminous areas of soil are, the easier it is to locate the boundary between them accurately and precisely. This is a fortuitous relationship. Because of it, conterminous areas of soil that are the most different generally can be separated most accurately and precisely in mapping.

THE ROLE OF TACIT KNOWLEDGE

The soil–landscape model is a very successful paradigm. It has captured the imagination and allegiance of a large number of practitioners, and is the driving force behind a large, enduring technical program. The National Cooperative Soil Survey program, using the soil–landscape paradigm, has prepared detailed soil maps on more than 600 million ha in the USA. There is an increasing demand for these maps and the soils information that accompanies them. Notwithstanding its success and power, the soil–landscape model has one major weakness — an extreme reliance on tacit knowledge. *Tacit knowledge* refers to information and techniques learned through experience. The role of

tacit knowledge in the soil survey and the problems associated with it are evaluated below.

Polanyi (1966) argued brilliantly that much of a scientist's success depends on tacit knowledge acquired through practice. His thesis proceeds from the simple premise that "we can know more than we can tell." For example, each of us can recognize a person's face, even among thousands of faces. However, none of us can explain how we distinguish one face from a thousand others. Those who have acquired tacit knowledge rarely are able to explain it to anyone else. Furthermore, they usually are unable to explicitly state the rationale behind decisions that are made using tacit knowledge. Medicine often is referred to as the "art" of healing. Many describe soil mapping as an art. Kuhn and Polanyi would argue that such "arts" actually are sciences based on a large reservoir of tacit knowledge. Applying the soil–landscape paradigm is almost totally dependent on the acquisition of tacit knowledge. Two concepts of human perception that are critical to this process are gestalt shifts and the recognition of natural families.

Gestalt Shifts

The ideas given here are based on an application of concepts advanced by Kuhn (1970) and Hanson (1969) to the mental process of mapping soils. To the untrained eye, the landscape is a dimly perceived backdrop for objects of more interest, such as trees, animals, or humans. In order to recognize and delineate soil bodies, beginning soil scientists first must learn to see the landscape as an entity unto itself. Then they must learn to recognize distinct soil–landscape units. This requires them to mentally carve the landscape up into facets and to visualize interactions and processes affecting the landscape and its facets. To accomplish these conceptual tasks, a soil scientist must learn to see the physical world in a new way. The formerly indistinct landscape must "shift" and then take on a new appearance. Most soil scientists make this conceptual shift after only a short time in the field. After this happens they are incapable of looking at a landscape without mentally breaking it up into distinct facets. Furthermore, they cannot even remember how landscapes appeared prior to the conceptual shift.

The process described above is analogous to the visual phenomenon commonly referred to as a gestalt shift. This refers to the reversible-perspective figures that appear in textbooks of Gestalt psychology (Kohler, 1980). A well-known example is the picture that at first glance looks like a young woman. However, as one stares at the picture, it seems to "shift" and change into an old woman. Kuhn draws an analogy between simple visual gestalt shifts and the kind of change in perception experienced by field soil scientists.

One cannot simply choose to experience a gestalt or conceptual shift (Kuhn, 1970). Instead, it is something that "seizes" one. For example, Pearce (1971) tells of a mathematics student in the final years of his doctoral studies in topology. After years of study, the student suddenly was "seized and changed" by the concepts of topology. According to Pearce, "The structure of his mind, and his resulting world, were never again the same as that of nonmathematicians."

Natural Families

After learning to recognize and delineate soil–landscape units, a more difficult task lies ahead. Soil scientists then must learn to place a large number of soil delineations into a much smaller number of similarity groups, or map units. In terms of human perception, they must learn to group soil delineations into what Wittgenstein (1976) calls "natural families." Following is a brief discussion of this concept.

Philosophers have asked, "What must one know in order to apply terms like *dog* or *leaf* or *dance* to objects or activities without disagreement among observers?" This kind of question is very old. It has been answered in the past by asserting that we must know consciously or intuitively all of the characteristics of a dog, or a leaf, or a dance (Wittgenstein, 1976). However, Wittgenstein disagreed. Considering the way we use language and the nature of the world to which we apply it, he reasoned that no such set of characteristics need exist. Instead, by recognizing only some of the attributes shared by some dances, or dogs, or leaves we are able to use the corresponding term. However, there is no set of characteristics that is simultaneously applicable to all members of the class and only to them. Instead, when observing an activity, we might apply the term *dance* because what we see bears a close "family resemblance" to a number of activities that, through experience, we have learned to call by that name.

Throughout life one learns to recognize many natural families and identify them quickly because there is "perceptual space" around them. This learning is almost entirely by trial and error. One rarely sits down with a child and says, "These are the characteristics that distinguish a joke," or "When you see an activity with these characteristics, it is a dance," and so on. Instead, each of us learns to recognize most of the things and activities we see and to group them into natural families through experience.

Natural families of soil delineations that can be interpreted similarly are the ultimate and elusive goal of soil mapping and classification. Achieving this goal represents an especially difficult conceptual task. The main difficulty arises from the fact that learning to do it is an iterative, trial-and-error process. One must learn to group soil delineations by recognizing and comparing only some of the attributes they share. Recognizing soil–landscape units and grouping them into natural families require the acquisition of a large amount of tacit knowledge.

IMPLICATIONS OF TACIT KNOWLEDGE

Knowledge and Linguistics

In the process of learning to recognize and delineate soil–landscape units and group them into natural families, one intuitively learns the main concepts of the soil–landscape paradigm. However, despite the fact that this paradigm has been the basis for a large technical program for many years, it has not been explicitly stated or written in any soils text or technical

document. The concepts of the paradigm have resided mostly in the minds of perceptive, experienced soil geographers, who use them regularly in their work. However, very few of them can express the concepts verbally. This is because they acquired them as this author did, intuitively or tacitly. The concepts of the paradigm were internalized by observing the relationships between soils and landscapes day after day in different areas. The fact that the soil–landscape paradigm has been used for decades and yet has not been expressed linguistically is a strong indication of its tacit nature.

An almost exclusive reliance on tacit knowledge to impart a paradigm is extremely inefficient. Hanson (1969) has argued convincingly that all human seeing has a linguistic component. He cited the example of Charles Darwin. During an expedition, Darwin and his companion could not see obvious features in a new environment simply because they had not been told about them or taught to see them. Darwin wrote (1902), "Neither of us saw a trace of the wonderful glacial phenomena all around us; we did not notice the plainly scored rocks, the perched boulders, the lateral and terminal moraines ... " As Hanson (1979) maintained, you must tell people what you know before you can show them what you see.

This idea has important ramifications for the soil survey. A paradigm that is not expressed linguistically can be learned only with great inefficiency and at considerable expense. It normally takes 2 to 3 yr for a new field soil scientist to thoroughly internalize the soil–landscape paradigm and begin to operate at the "journeyman" level.

Knowledge and Maps

Much of the knowledge gathered using the soil–landscape paradigm is in the form of maps. This, too, causes serious inefficiencies. Hanson (1969) asserted that, if research findings are not expressed linguistically — not written down, they will not affect the general body of scientific knowledge. He made the following distinction between pictures and language: "It is a point of profound logical significance that the pictures on our retinas and the pictures sense-datum theorists talk about are first and foremost pictures, while what is called scientific knowledge is first and foremost expressed in language." He describes maps as occupying an intermediate position between pictures and human language, stating " ... there is a logical gulf between pictures and language which maps partially bridge." He goes on to say that maps are " ... a half-way house between pictures and modern language; unlike pure pictures, maps have the rudiments of a vocabulary."

Since maps have only the rudiments of a vocabulary, they are not efficient conveyors of knowledge. Maps, including soil maps, mostly serve as pictorial representations of some aspects of a real terrain. In order to impart specific knowledge about that terrain, icons are required (Hanson, 1969). *Icons* are symbols placed on a map and defined or described in order to convey information. Map-unit symbols and ad hoc symbols on soil maps are examples of icons. It is important to note that, when employing maps and icons, most of the knowledge still is imparted linguistically; one must read about the icon to acquire information. Abstracting additional knowledge (knowledge not conveyed by icons) from a map requires that one possess some level of prior knowledge. For example, in order to understand the many relationships between soils and landscapes shown on a soil map, the viewer must possess similar basic knowledge as the individual who made the map.

The iconic nature of maps severely limits the kind and amount of knowledge they can convey. Maps can efficiently provide information about individual points or areas identified by icons. However, they are not effective in conveying scientific concepts or complex relationships that are shown by the imagery. Such knowledge must be expressed linguistically and in highly sophisticated language to be understood by those not already acquainted with the relevant concepts and relationships.

MAINTAINING THE PARADIGM

Typically, scientific paradigms are maintained and reinforced by university instruction, textbooks, and scientific publications. However, explicit information concerning the soil–landscape paradigm is nearly absent from soil science curricula and texts. Furthermore, there has been little substantive academic research dealing with soils as natural bodies on the landscape. The applied research (soil mapping and investigations) that has taken place under the guidance of the soil–landscape paradigm has generated a vast amount of knowledge concerning the soils of the USA. As with the paradigm itself, however, much of this information is not part of the scientific literature. Instead, it remains in the form of maps, a nonlinguistic form that is not available to the larger soil science community.

This raises an interesting and important question: considering its reliance on tacit knowledge, how is the soil–landscape paradigm maintained and reinforced? This is accomplished largely by requiring each practitioner to take part in a continuing socialization process. On learning the basic soil–landscape model, a new soil scientist becomes part of a close-knit scientific community. The mores of this community are constantly reinforced. This is done through frequent communal gatherings at every level.

In the U.S., a field review, normally a week long, is held yearly in every progressive soil survey project. These reviews are attended by technical supervisors from the Soil Conservation Service state office and, often, by their regional counterparts. Representatives of the experiment station and other cooperating agencies in the state also take part. The stated purpose of field reviews is to provide technical oversight and guidance to the soil survey project. However, it also accomplishes another important goal. It reinforces the paradigm. Ideally, the project leader and party members end the review convinced that they are involved in important scientific work and that they are part of an enduring scientific community.

Such interaction and paradigm reinforcement take place at every level of the National Cooperative Soil Survey. Communal gatherings include soil survey conferences held annually in each state and confer-

ences held in alternate years at the regional and national level. As with the field reviews, practitioners leave these meetings with the confidence that both the paradigm and the pleasant communal scientific life it supports are important and will continue to thrive. As long as much of the soil survey is based on tacit knowledge, formal meetings of National Cooperative Soil Survey cooperators will serve the vital purpose of maintaining the paradigm on which the organization is based. This can be as important as any technical or managerial achievements. (See Shapiro [1987] for a discussion of the role of formal gatherings in maintaining scientific communities.)

CONCLUSION AND RECOMMENDATIONS

I have categorized the soil survey as paradigm-based science. I also have argued that the soil–landscape paradigm, on which soil survey is based, is overly dependent on tacit knowledge. For example, relying on tacit processes to teach the soil–landscape paradigm is very inefficient. Furthermore, much of the knowledge that has resulted from applying the paradigm remains on maps, which do not convey concepts or complex information efficiently. This is an additional cause for concern. Because it has remained on maps, much valuable information gathered during a period of many years has not become part of the soil science literature.

As has been pointed out before, most human learning has a linguistic component. Hanson (1969) asserted that employing language to reduce reliance on tacit knowledge is an almost uniquely human ability — and one to which we owe much of our progress as a species. What one can observe and learn depends largely on what one has been prepared to observe and learn. According to Lewes (1879, p. 108), " ... the new object presented to Sense, or the new idea presented to Thought, must also be soluble in old experiences, be recognized as like them, otherwise it will be unperceived, uncomprehended." New visual experiences can be perceived more readily if some comprehensive framework of knowledge has been established into which the new visual experience can be fitted.

Hanson (1969) and others use the term *set* to refer to the process of preparing a person to see new phenomena and to see it in a certain way. Studies have shown (Hanson, 1969) that, if an observer is "set" to see the names of animals, he will read the nonsense syllables sael and wharl as seal and whale. However, if he is "set" to see words related to boats, he will immediately perceive the same syllables as sail and wharf. Students or trainees can be "set" to perceive soil–landscape units more easily by prior explicit instruction in the soil–landscape paradigm.

If all new soil scientists received explicit instruction concerning the soil–landscape paradigm, nearly all of them would learn it. Furthermore, if they were "set" properly, their learning time could be significantly reduced. It is even possible that, by using linguistics to draw the right series of mental pictures, one could teach the basics of the paradigm entirely in a classroom setting.

In addition to teaching the paradigm more efficiently, the information acquired by applying it must be made more widely available. The concepts inherent in the soil–landscape paradigm must be explicitly expressed in soils textbooks and taught to students. Furthermore, the mass of information that has resulted from applying the paradigm must be abstracted from soil maps, conceptualized, and published in the soil science literature. Preparing detailed maps requires that one determine the many geographic and genetic relationships among the soils in an area. After the soil maps are prepared, however, the landscape and soil relationships that made them possible are rarely communicated. As a result, it is not uncommon for a researcher to "discover" relationships that have already been recognized by field soil scientists and used for many years in mapping soils.

The last and perhaps most important recommendation is that soil scientists should try to gain a new appreciation for the overwhelming power of ideas and concepts. Mental constructs such as paradigms are of paramount importance in everything we do. To paraphrase a statement attributed to N.W. Pirie (Webster, 1977), "A sensible philosophy controlled by a relevant set of concepts ... can nearly act as a substitute for genius."

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NSSH Part 627 (08-Exhibit 2)

Legend Development and Data Collection

Documentation (627.08)

(a) Definition

Soil survey documentation is scientific data from measurements and observations of basic soil properties and qualities and of spatial arrangements, that are collected in the field or remotely sensed using standardized procedures. This data is systematically recorded. Soil survey documentation is used to verify soil-landscape models, interpretations, and projections for use. The dominant type of documentation varies by soil order (Exhibit 627-8). The percentages of delineations that use any one type of documentation vary by the size and number of delineations of a map unit in a physiographic area. The information is presented as geographical descriptions of landscapes and boundaries, soil profiles, soil layers, chemical and physical properties, or temporal condition. It has spatial, temporal, physical, and chemical aspects. Documentation assures proper soil classification, uniform and consistent mapping, and supports inferences for application of the information to similar landscapes.

Documentation is collected over time and permanently archived. The information is cumulative. It is organized by major land resource area. Documentation progressively refines and improves soil-landscape models.

The soil survey project office organizes and analyzes support data and move it into the National Soil Information System. Field notes, including soil pedon descriptions, map unit descriptions, transects, laboratory data, and notes of an interpretive nature supplement soil maps. Soil maps and this descriptive information in the database become the primary records of a soil survey. Chapter 5 of the Soil Survey Manual gives helpful information about field notes and soil descriptions.

(b) Purpose of Documentation

Documentation is collected for specific outcomes within each survey area. The main outcomes are:

- To be able to develop science based soil-landscape models so we can delineate polygons of like soils
- To be able to build and store property data in a permanent database accessible to users.
- To quantify soil spatial variability in order to make logical breaks in soil landscapes.

- To better communicate with soil scientists and related professions (nomenclature, taxonomy, etc)
- To correlate ecological sites with soils
- To be able to classify and correlate soils consistently
- To be able to develop and test interpretations
- To be able to test and report the reliability of soil survey information

(c) Specifying Documentation

The memorandum of understanding and the project plan specify the kind and amount of support data required. The requirements for documentation written into the memorandum are based on the evaluation of the deficiencies in the map units of the previous soil survey. Reference part 610.04. For previously unmapped areas the requirements for documentation are based on the evaluation of the landscapes and map units of the surveys adjacent to the area. Generally map units that are not revised do not need further documentation other than that provided in the evaluation. Map units revised or redesigned need full documentation within the major land resource area.

Because of the variable nature of parent material, landscape patterns, uniformity, land use, user needs, scale, access, and past documentation, flexibility is needed for requirements in the type and amount of field documentation for map units within each survey area. Agreements on documentation requirements that differ from standard field description standards should be spelled out in the memorandum of understanding for each survey area before field work starts. The MLRA office should take the lead, as part of quality assurance, in assuring these standards are reasonable and adequate for correlation and interpretation and are addressed in the memorandum of understanding. Reference Exhibit 606-1.

(d) Kinds Of Documentation

(1) Field Notes

Field notes are essential for the preparation of the descriptive legend and soil survey manuscript because:

- many of the facts obtained in the field cannot be recorded on the map or in standard soil descriptions;
- the soil scientist cannot remember the details of all field observations, or the soil scientist may retire or transfer before completing the survey;
- they help the project office to achieve consistent work among the project members;

- they provide the data necessary for describing, classifying, and interpreting soils;
- they provide data for long term records; and
- they aid in developing and recording the map unit concept and criteria.

Soil scientists take field notes as they progressively map the soils. They:

- record them on location at the time of the observation;
- emphasize documenting the ordinary, the prevalent, and the commonplace;
- if not a direct observation, clearly identify location, date, author, soil component, and source;
- use standard terminology and standard database programs;
- clearly separate observations from conclusions and speculations;
- summarize at regular intervals to determine the status of the documentation effort;
- add to the site observation table in NASIS; and
- file in a logical manner, preferably by map unit component and map unit, for easy reference.

Interpretive field notes are important in documenting soil behavior in the survey area. Interpretive notes result from direct observation or from information provided by resource specialists, farmers, extension personnel, agricultural teachers, fertilizer and farm equipment dealers, soil consultants, environmental scientists, county sanitarians, engineers, and other persons with experience or knowledge of soil relationships.

(2) Pedon Descriptions

Pedon descriptions are the primary records for soil identification, classification, and interpretation. Chapters 3 and 5 of the *Soil Survey Manual* provide helpful information, guidance, and standard terminology for describing soils. Typical pedons characterize each named component in a map unit. The soil survey project office maintains a map that locates soil description sites, especially the typical pedons. Describe soils as they occur in order to represent each map unit component. One pedon description represents each component. It is permissible to use pedons from surveys sharing the data mapunit from within the same major land resource area and MLRA legend. Tentatively classify all pedons at the time when they are described. After sufficient descriptions have been taken, establish a central concept and range for a kind of soil. Consult the official soil series descriptions to determine proper series placement. If the soil differs significantly from all recognized soil series in the same taxonomic family, classify the soil in the lowest possible category of soil taxonomy.

Pedons that have all soil characteristics representative of a given kind of soil often are difficult to locate or do not exist in an individual survey area. Soil scientists must objectively locate and describe pedons that are representative of the kind of soil in the area. Soil descriptions must be complete and legible. It is important to give the exact geographic location of pedons to allow for spatial analysis and revisitation of the sites.

(3) Map Unit Descriptions

The collection of field notes, transects, and soil descriptions provide the basic information needed to adequately describe map units. The notes and descriptions:

- characterize the soils within the map unit;
- determine the patterns of occurrence of different kinds of soils within the map unit, their proportionate extent, and their position on the landform; and
- determine the relationships of one map unit to another and the distinction between similar map units to support the descriptive legend.

(4) Images

Slides, black and white photos, digital images, and color photos taken during the soil survey illustrate and document field conditions for soil survey reports, information activities, and training sessions. Soil profiles, landscapes, vegetation patterns, typical landforms, rock exposure, and the results of management practices applied to particular soils are needed.

(5) Soil Survey Investigations

Soil survey investigations may take the form of laboratory data obtained by collecting samples for chemical, physical, or engineering analysis. Other investigations may result in documentation of soil temperature, moisture, or other soil property or quality. Reference part 631 for information on soil investigations.

(e) Field Description Standards

The soil survey project office ensures the systematic collection of documentation by providing each project member with a list of specific instructions about the kind of information needed for each map unit and soil map unit component.

The memorandum of understanding for the survey area provides guidance for the type and amount of documentation. Documentation needs and standards may vary by map unit within the same

survey area. Flexibility of guidance allows for sufficient data collection for each map, yet avoids the excess time and expense of redundant or superfluous data.

(1) Proposed series require descriptions of at least 5 pedons for new series with an extent of less than 2,000 acres. New series with an extent of over 20,000 acres require ten pedon descriptions. The number and distribution of pedon descriptions must be adequate to classify, differentiate and develop range of characteristics. Larger acreage units require more pedons descriptions to assure reasonable spatial representation across its extent.

Laboratory data and field notes supplement these requirements. Part 614.06 of this handbook provides helpful information on proposing a soil series

(2) Each map unit soil component has a unique description. This representative pedon description exhibits typical properties and horizonation of the map unit component as it exists within the major land resource area. Each major soil component named within a map unit of the major land resource area legend requires one pedon description from the map unit. Minor components that are not named in a map unit of the legend but that occur in the component list of the database need a minimum of one pedon description. Provisional map units are exempted. This documentation is adequate for map units where the extent of the map unit is up to 3,000 acres. Where the extent is over 3,000 acres, the amount of additional descriptions are agreed upon and recorded in the memorandum of understanding. Factors that need to be considered are uniformity of material, scale, land use, and access.

To ensure that documentation is adequate for the correlation of soil component names to established soil series or higher taxonomic categories, at least three pedon descriptions are required for each taxon used in the legend. Descriptions gathered to typify the map unit component as mentioned above and descriptions within adjacent surveys within the major land resource area are included in this total.

(3) Map units require a minimum of 30 recorded points for each map unit to document the composition. The points need to be distributed throughout the full extent of the map unit to account for spatial variability. Depending upon the nature of the map unit, the points can come from a fixed interval transect, a line transect (points selected to represent line segments related to vegetation, hillslope position, photo tone, etc.) or other techniques to assure composition. This documentation is adequate where the extent of the map units are less than 2,000 acres. Where the extent is over 2,000 acres, add an additional 10 recorded points for each 4,000 acres. Sufficient documentation

typically exists when the number of recorded points reach 60, given adequate spatial distribution. Due to unique situations and variability, the memorandum of understanding state specific requirements as needed based on uniformity of material, scale, land use, or access. Where applicable, the use of statistics can be helpful in determining the adequacy of recorded points.

(4) Exceptions to the minimum standards for documentation of map units and map unit components apply when adding small acreage map units along the boundary of an ongoing soil survey or modern published soil survey. Part 609.05 of this handbook provides more details on map units of small extent. In these cases use the documentation from the joining soil survey area that has the larger acreage for correlation.

The project office regularly reviews and summarizes all documentation. Where applicable, a statistical analysis of data is done to objectively evaluate soil properties and map unit composition. The descriptive legend, manuscript, and database are updated periodically based on progressively gathered documentation. Documentation undergoes a quality assurance review at regular intervals by the MLRA office. Determinations are made about the documentation in regard to:

- attaining the outcomes as stated above,
- meeting the Field Description Standards (or standards modified in the MOU), and
- identifying the need for additional documentation.